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Abstract

The report presents the implementation of the PWR power plant model PWR-PLASIM described in Risø Report No. 318. It should serve as a users guide for both the operator, who runs the model, and the experienced simulation engineer, who modifies the input data or details in the model.

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Abstract to

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1. GENERAL INFORMATION

This report presents the implementation of the PWR power station model described in Ref. 1. Numerical data for the Westinghouse Surry-1 power station have been used as a test example, as most of the data needed for the model could be found in the available information, Refs. 2 and 3. For the turbine-reheater, however, some additional data had to be estimated from descriptions of the Obrigheim and Oyster Creek turbines.

The presentation follows the layout in Ref. 1. The same division in chapters and numbering of equations are used. The intention is that the report should serve as a handbook for the experienced simulation engineer, and facilitate the insertion of new data sets or modifications for special investigations. The present chapter, together with appendices A to F, should be sufficient to run the model, when it is prepared for a given station. Some information fundamental both for operation and modification of the model is given here, while the appendices contain all program listings, analog diagrams, potentiometer lists and other related information.

The analog part of the model is stored on a patchpanel according to the diagrams in the appendices. Any modification introduced later on must be thoroughly documented. The programs in the version given in the appendices are stored on the DEC-tape named "PWR DEC. 74" together with the system libraries as used at the time of storage. No modifications whatsoever may be introduced into this DEC-tape; it shall at all times serve as a basic model until and if a new, fully documented, version is available. The program system contains the following files for the station model:

PWR.8B : The main PDP8 code section

PWR1.8B: Neutron kinetic calculation in FPP-code

PWR2.8B: Calculations for the primary circulation loop, the steam generator, the turbine and the pressuriser in FPP-code.

PWR3.8B: FPP-code sections for IC input and [illegible] input and logging of main variables [illegible]

PWR.IC : A set of IC-data for full load [illegible] PWR.ST and PWR.SP.

PWR.SP : Potentiometer data for the analog model.

PWR.ST : A set of static data for the reactor calculated by a static program.

PWR.SV : The binary version of PWR.8B, PWR1.8B, PWR2.8B and PWR3.8B

The DEC-tape further contains the files for the independent models of separate components:

P1.8B : The pressuriser simulation program.

P2.FT : The ten-section fuel model.

P3.FT : The steam generator model.

P3100.IC: A set of IC values for the steam generator at full load.

Appendix K gives a list of the contents of the DEC-tape.

The programs with the file name extension FT are written in Fortran IV, while those with extension 8B are written in a macro language called HYBAL with macro instructions and subroutines developed just for hybrid simulation on the EAI680-PDP8-FPP12 machine.

The following section gives some basic operating instructions and explains the computation sequence.

After installing the patchpanel on the analog machine, the potentiometers must be adjusted by the Fortran program SETAN according to the potentiometer list PWR.SP. The Q-potentiometers must be adjusted manually.

The simulation program PWR.SV can then be started. It prints a message on the DEC-writer to remind the operator of the adjustments of limiters and pulse generators listed in appendix F, and of the switch 0 (see below).

The computation must be started on a set of either IC-data for the whole station, or static data for the reactor alone. The IC-data are inserted automatically from the disc file PWR.IC during the analog IC period, when the logic connection to DI(11) is in function. The insertion is announced by a message containing the regulating rod position and the electrical load. The two potentiometers, Q14 and Q29, must be adjusted accordingly. The computations start bumpless, when the analog computer is set at OPERATE. The PDP8 is synchronized via pulses over DI(0) at a rate of 10 per sec. The same pulses synchronize the display, where one or more variables along the reactor axis may be selected. The time

representing the length of the space axis may be adjusted in the range 10-25 mS by MM 0.

For a new set of reactor conditions without a full set of IC-data a set of static data must be generated by the static program described in Ref. 4. The data must be stored in a disc file PWR.ST before they can be used in PWR.SV. They are inserted into PWR.SV by printing the number "2" on the DEC-writer with the analog machine in PC mode. The insertion is announced on the DEC-writer by a message containing the regulating rod position and the approximate power level. The two potentiometers, Q14 and Q29, must be adjusted accordingly. When the computation are started via the analog IC-mode, the connection to DI(11) must be withdrawn to avoid insertion of IC-data from file PWR.IC. The computations do not start bumpless, as it is most likely that the IC-data in the potentiometer list do not fit the new reactor condition exactly, but within a few minutes a new stationary state with the required value of reactor load and steam pressure may be found by adjustments of the regulating rod, the boron acid concentration and the electrical power load. Fast transients in the first few seconds will most likely overload the output channels from the pressuriser model. This can be avoided and the transient time decreased by pressing switch 0 before the start. The switch is connected to DI(2) which controls the operation of the pressuriser, taking it out of action for switch 0 equal to "1". The pressuriser is reconnected, when the transients have died out. The new state may be stored on a disc file PWR.IC by typing "1" on the DEC-writer with the analog computer in HOLD mode. For later use of the file, the IC-data in the potentiometer list must be corrected manually by reading the integrator outputs, and both new files must be stored as a set on DEC-tape. The main variables may be listed on the DEC-writer for documentation by typing "3" on the DEC-writer with the analog machine in HOLD mode.

The computations are controlled by the PDP 8 code program in file PWR.8B synchronized by pulses on DI(0) conditioned by the OPERATE state. A pulse starts the calculation [illegible] routine HYDRA1, which controls the hybrid [illegible] reactor core heat transfer. Then follows [illegible] for FPP calculations of the primary loop [illegible] the steam generator parameters [illegible] HYDRA2 initiates these [illegible]

FPP2 and TURB, and calculates the sum of the reactor thermal power for later use. Next follows, in HYDRA3, the calculation of the boron acid distribution in the primary loop in 12-bit integer arithmetic. HYDRA4 reads the regulating rod position and calculates the rod density in the core sections ready for use in the neutron kinetics routine. The final PDP8-routine is HYDRA5, which is started when the FPP unit finishes the calculations initiated in HYDRA2. HYDRA5 starts calculating the neutron flux distribution in the FPP-routine FPP1, performs all the adjustments of analog outputs and the MDACs, and finally starts the FPP3 routine with calculation of the delayed neutron concentrations, when the neutron kinetic routine is finished. The FPP3 routine is followed by the PROP routine with the calculations for the pressuriser. From HYDRA5 PDP8 goes back to the waiting loop, while the FPP unit continues the calculations just started, which normally last some few milliseconds into the next time interval.

The calculations may run into error conditions which prevent continuation. In these cases a message is typed on the DEC-writer and the program stopped with a jump to monitor. A list of error messages is given in Appendix F.

The waiting loop in the PDP8 code contains a test of the DEC-writer request. If a request is detected, the character will be printed and action taken according to the following list.

0: Go to the FPP input-output test routine belonging to the HYBAL language.

1: Transfer a set of IC-data for the present steady state condition to the disc file PWR.IC.

2: Transfer a set of reactor static data from disc file PWR.ST to the data areas in the core for the active PWR.SV program.

3: Type a list with main variables and parameters on the DEC-writer.

Other characters: no action.

Analog simulation requires amplitude scaling. The variable range on the analog machine is defined as ±1 corresponding to ±10V. A variable X with the variation $\pm X_{max}$ must be used with a scale factor SF X = $1/X_{max}$. A variable with a scale factor is written in square brackets, e.g. $[0.02\ T_c]$. The same convention is used for integer variables in the PDP8 where ±1 corresponds to the

integer ±2048. In a single case another type of scale factor is needed for integer arithmetic; the meaning is given by the equation:

X in machine integer units = {(SF X)×X} .

The scale factor is chosen so the maximum value of X corresponds to the integer 4096 for positive variables and ±2048 for dual signed variables. The analog input and output units work with dual signed integers, while the MDACs only use positive integers.

The interface units will often be referred to by abbreviations as follows:

AI: analog input channels

AO: analog output channels

DI: digital input

DO: digital output

MDAC: multiplying digital to analog converters

Other abbreviations are:

A: analog amplifier

P and Q: potentiometers

DFG: diode function generators

MM: Monostable timers given adjustable pulse length

2. NEUTRON KINETICS

Geometrical data

Number of core sections: 14

Length of core : 365 cm

Δx = 365/14 = 26.07 cm

V_f = 1.764 m^3

Physical data

The kinetic parameters D, Σ_a and $\nu\Sigma_f$ have been calculated by static programs as second degree polynomials in the 5 variables: T_u, T_c, ρ_m, C_b and CR. The control rod density CR has been normalized as a quantity between 0 and 1. The other 4 variables are used with suppressed zero points. The following values are used:

T_u : 735 °C

T_c : 298 °C

ρ_m : 0.7296 g/cm^3

C_b : 1500 ppm

The general formulae are:

$$a_1\Delta T_c^2 + a_2\Delta T_c + a_3\Delta\rho_m^2 + a_4\Delta\rho_m + a_5\Delta C_b^2 + a_6\Delta C_b + a_7 CR + a_8\Delta T_u^2$$

$$+ a_9\Delta T_u + a_{10}$$

For the reflector sections, a_8 and a_9 are omitted.

In the diffusion equation Σ_a and $\nu\Sigma_f$ are always used together in the common expression $(1-\beta)\nu\Sigma_f-\Sigma_a$, so it is an advantage to use a polynomial for $(\nu\Sigma_f-\Sigma_a)$, completely eliminating the need for Σ_a alone. $\nu\Sigma_f$ alone is needed for calculation of the delayed neutrons and the thermal power, but here a less accurate calculation is possible. The variation of $\nu\Sigma_f$ with T_u and T_c is less than 1% in the temperature range of interest, so it is completely neglected. The variation with C_b is nearly linear below 2000 ppm, which is the upper limit, so only a first order term for C_b is used. The terms for ρ_m and CR are used unchanged. All the data for the kinetic polynomials are given in table 2.1.

The delayed neutrons are represented by 3 groups with the following data:

β_1 = 992E-6 $\qquad \lambda_1$ = 1.82 s^{-1}

β_2 = 3840E-6 $\qquad \lambda_2$ = 0.249 s^{-1}

β_3 = 1616E-6 $\qquad \lambda_3$ = 0.0288 s^{-1}

β = 6448E-6

Data for conversion of neutron flux ϕ to thermal power N:

A = 0.3E-10 J/fission

ν = 2.43 neutrons/fission

Insertion in eq. (2.9) gives:

$$N = (2.18E-11)\nu\Sigma_f\phi \quad \text{MW/section} \qquad (2.9)$$

2.1. Digital routines

The kinetic equations are solved by the digital routines FPP1 and FPP3 in file PWR1.8B, appendix A.

The first file page contains all the numerical data and variables.

The second file page contains the routine for calculation of the kinetic parameters and the coefficients in the matrix equation (2.8). The integer variables T_u, T_c, ρ_m, C_b and CR are transferred from the arrays A0-A15 in the PDP8 code section in file PWR.8B and converted to floating point form.

The third file page contains the routine for solution of the equation (2.8), calculation of $\nu\Sigma_f\phi$ for the next routine and of the thermal power N, which is converted to integer form and stored in array N, with a scale factor 1/500. By the conversion overflow is possible during power transients. A test for overflow is carried out for fuel sections 3-10 and announced by a TRAP6 message no. 0-7.

The fourth file page contains the routine FPP3 for calculation of the delayed neutrons. It is not coupled to the preceding routine FPP1, but is activated independently.

The regulating rod position is an independent control variable, which is inserted via AI7 through the PDP8 routine HYDRA4 in file PWR.8B. The rod density in each section is represented by a number between 0 and -2048 inclusive.

Numerical data in file PWR1.8B

Array KD: coefficients a_1-a_{10} for D

" KSFA: " " " $(\nu\Sigma_f-\Sigma_a)$ } in the core

" KSF: " " " $\nu\Sigma_f$

" KDØ: " a_1-a_8 " D } in the reflector

" KSAØ: " " " Σ_a

DX2 = Δx^2 = 679.645

F3DX = $3\Delta x$ = 78.21

DXR = $1/\Delta x$ = 0.038358

BETA = β = 6.448E-3

NPTU = "Analog zeropoint" - "Digital zeropoint" for T_u

= 800 - 735 = 65

NPTC = do. for T_c

= 300 - 298 = 2

NPRO = do. for ρ_m

= 0.5 - 0.7296 = -0.2296

NPBO = do. for C_b

= 0 - 1500 = -1500

SFTU = -1/(SF T_u × 2048) = -500/2048 = -2.4414E-1

SFTC = 1/(SF T_c × 2048) = 50/2048 = 2.4414E-2

SRRO = 1/(SF ρ_m × 2048) = 0.5/2048 = 2.4414E-4

SFBO = 2000/4096 = 4.8828E-1

SFCR = -(weighting factor for regulating rod/2048)

= e.g. -0.25/2048 = -1.2207E-4

(updated by input of static data or IC data)

SFN = 2.18E-11 × 4096 × SF N = 2.18E-11 × 4096/500 = 1.7859E-10

(equation (2.9)

LM1 = λ_1 = 1.82

LM2 = λ_2 = 0.249

LM3 = λ_3 = 0.0288

CN1K2 = $(2-\lambda_1\Delta t)/(2+\lambda_1\Delta t)$ = 0.833181

CN1K1 = $2\beta_1\Delta t/(2-\lambda_1\Delta t)$ = 1.091309E-4

CN2K2 = $(2-\lambda_2\Delta t)/(2+\lambda_2\Delta t)$ = 0.975406

CN2K1 = $2\beta_2\Delta t/(2-\lambda_2\Delta t)$ = 3.888411E-4

CN3K2 = $(2-\lambda_3\Delta t)/(2+\lambda_3\Delta t)$ = 0.997124

CN3K1 = $2\beta_3\Delta t/(2-\lambda_3\Delta t)$ = 1.618330E-4

Arrays for parameters and variables

CCR: Fixed control rod density.

CJI: Elements below the diagonal in {C} with first position empty.

CJJ: Elements in the diagonal in {C}.

CJK: Elements above the diagonal in {C} with last position empty.

PHI: ϕ

FNP: $\nu\Sigma_f\phi$

NYSF: $\nu\Sigma_f$

SAZE: Fixed contribution to Σ_a from xenon poisoning calculated in and transferred from the static program.

SLCN: $\Sigma\lambda C_n$

CN1: C_1

CN2: C_2

CN3: C_3

	D	Σ_a	$\nu\Sigma_f$	$\nu\Sigma_f-\Sigma_a$	$\nu\Sigma_f$ simplified
a_1	1.275E-6	6.925E-8	1.0775E-7	3.85E-8	-
a_2	-4.700E-5	-1.485E-6	-2.150E-6	-6.65E-7	-
a_3	6.4587	-1.3714E-1	-1.459E-1	-8.76E-3	-1.459E-1
a_4	-4.7908E-1	1.2717E-2	1.3522E-2	8.05E-4	1.3522E-2
a_5	1.400E-9	7.800E-11	3.016E-10	2.236E-10	-
a_6	1.100E-5	3.402E-7	-1.724E-6	-2.0642E-6	-1.9E-6
a_7	6.6E-3	2.4E-4	-6.4E-4	-8.8E-4	-6.4E-4
a_8	2.7665E-9	1.7956E-10	4.8171E-10	3.0215E-10	-
a_9	4.5499E-6	2.1279E-7	-3.9407E-7	-6.0686E-7	-
a_{10}	1.2033	2.55E-2	2.6391E-2	8.91E-4	2.6391E-2

Table 2.1

Coefficients for polynomial calculation of kinetic parameters.

3. THE FUEL MODEL

Geometrical core data

Δx = 26.07 cm

M_u = 204 × 157 = 32028

r_u = 0.4655 cm

Δr_g = 0.0080 cm

Δr_{ca} = 0.0620 cm

r_{ca} = 0.5355 cm

H_{ca} = 3.170 cm^2/cm

O_{ca} = 280.9 m^2/section

De_c = 0.01435 m

A_c = 3.88 m^2

V_c = 1.012 m^3/section

Physical fuel data

k_g = 4.0 W/cm°C

λ_{ca} = 0.15 "

Z_{ca} = $\Delta r_{ca}/(H_{ca}\lambda_{ca})$ = 0.1304 cm°C/W

Z_{gca} = Z_{ca} + $1/k_g$ = 0.3804 "

Z_{gca} per section = 0.4556 °C/MW

ρ_{ca} = 6.5 g/cm^3

c_{ca} = 0.31 J/g°C

ρ_u = 10.0 g/cm^3

c_u = 0.32 J/g°C

C_{ca} = 0.3307 MJ/°C per section

C_u = 1.819 " " "

λ_u = $(4.788E-13)T^3 + 38.24/(T + 129.4)$ W/cm°C (T in °K)

3.1. The ten-shell section fuel model

The model has been implemented in a Fortran program suitable for calculation of transients for variation in either the heat production, N, or the coolant temperature, T_c. The program works in real time synchronized from the analog computer. It receives the input variables N and T_c from analog inputs, and delivers the output via analog output channels and the DEC-writer. The program and the analog diagram are given in appendix G with implementation for steps in N and T_c.

The program is divided into sections numbers 1 to 9. Section 3 contains all the geometrical and physical data in DATA statements. Section 4 calculates some fixed parameters and resets digital inputs and outputs. Section 5 contains a waiting loop for the timing impulse via DI6; when the impulse arrives the calculation starts by reading the input variables which are:

AI0: (N/500)

AI1: $((T_{ci}-200)/50)$.

The time step is 0.1 sec. so 10 [illegible]
calculation. Sections 6 and 7 [illegible]
matrix equation (1.1.6) and [illegible]

some variables for analog outputs and performs the output function. The output variables with scale factors and zeropoints are:

A00: $((T(1) - 1500)/1000)$

A01: $((T_{mean} - 1000)/500)$

A02: $((T(10) - 500)/250)$

A03: $((T_{ug} - 500)/200)$

A04: $((T_{ca} - 300)/100)$

A05: $((Q_c - 250)/250)$

Output printout can also be obtained at the DEC-writer by a signal at DI7. For every sampling time the program asks if DI7 is set and gives a printout if it is true. A periodic printout can be obtained with the counter circuit shown in the analog diagram; the period can be selected by the preset time thumb wheels. The variables in the printout are the ten T_u temperatures on the first line, and the following variables on the second line: T_u(mean), T_{ug}, T_{ca} and Q_c.

3.2. The two-point fuel model

The equations (3.2.1) and (3.2.2) are given here with numerical values, but all other details are given in the next chapter, as all the core heat transfer equations are used in one hybrid routine.

$$\left.\begin{aligned}
\dot{T}_u &= 0.5498(N-k_f(T_u-T_{ca})) \\
\dot{T}_{ca} &= 3.0239(k_f(T_u-T_{ca})-Q_c) \\
\frac{1}{k_f} &= Z_{ugca} = \frac{4.65E-6}{Z_u} + 0.4556 \\
T_{ug} &= T_{ca} + 0.4556\, k_f\, (T_u-T_{ca}) \\
\lambda_u &= F_\lambda(\tfrac{1}{2}(T_u-T_{ug})) \\
Q_u &= k_f(T_u-T_{ca})
\end{aligned}\right\}(3.2.1)$$

$$\left.\begin{aligned}
T_u(n+1) &= T_u(n) + \Delta_t T_u \\
\Delta_t T_u &= 0.05498(N(n)-k_f(T_u(n+\tfrac{1}{2})-T_{ca}(n+\tfrac{1}{2}))) \\
T_{ca}(n+1) &= T_{ca}(n) + \Delta_t T_{ca} \\
\Delta_t T_{ca} &= 0.3024(k_f(T_u(n+\tfrac{1}{2})-T_{ca}(n+\tfrac{1}{2}))-Q_c(n+\tfrac{1}{2}))
\end{aligned}\right\}(3.2.2)$$

The coefficient K_u = 4.65E-6 is selected so T_u obtains the same static values as the T_u mean value for the 10-shell section at a section load of 250 MW.

4. THE PRIMARY CIRCUIT WITH HEAT TRANSPORT AND BORON ACID CONCENTRATION

4.1. Heat transfer in core

All geometrical data are included in the list in chapter 3.

Only some few physical parameters, which are nearly constant over the working range or are of minor importance, are taken as constants. These are:

$H_c(T)$ = 0.92 KJ/kg°C (kg/m s)$^{0.2}$	for eq.	(4.5)
$h_{fg}\rho_{gs}$ = 97.1 MJ/m^3	" "	(4.9)
ρ_f = 725 kg/m^3	" "	(4.9)
$\rho_f-\rho_{gs}$ = 630 kg/m^3	" "	(4.10)

Other parameters are taken as temperature-dependent functions.

The equations with numerical values are listed below. Eq. (4.6) is simplified by using $\exp(p_p/43.4)$ as a constant. It is justified by small variations in the primary pressure p_p and by the quadratic term $(T_{ca} - T_{ps})^2$, which makes T_{ca} insensitive to variations in the coefficient.

$$\left.\begin{aligned}
T_c(j,n+1) &= T_c(j-1,n+1)+\frac{1}{W_c}(\frac{Q_t(j)}{c_p} -10.12\, \rho_f \Delta_t T_c(j,n+1)) \\
\Delta_t T_c(j,n+1) &= T_c(j,n+1) - T_c(j,n)
\end{aligned}\right\}(4.[illegible])$$

$Q_{c1} = 4.695E-3\ W_c^{0.8}(T_{ca}-T_c)$ [illegible]

$Q_{c2} = 17.57(T_{ca}-T_{ps})^2$ [illegible]

$Q_b = Q_c \cdot f_v(T_{ps}-T_c)$ [illegible]

$Q_t = Q_c-Q_b$

$\alpha(j,n+1) = \alpha(j-1,n+1) + \frac{725}{W_c}(\frac{Q_b(j)}{}$ [illegible]

$\alpha_t(j,n+1) = \alpha(j,n+1)$ [illegible]

$\rho_m = \rho_f -$ [illegible]

These equations are solved together with the fuel equations in one hybrid routine, where the calculations are done by analog components with the digital machine as coordinator and store medium. The same circuits are used for all the core sections on a serial basis with parallel analog calculations. This gives a computing time of about 1 ms per section. The input to the routine is the thermal power N, the coolant inlet temperature T_{ci}, with the coolant flow rate as a variable input parameter. The output variables are temperature profiles for the fuel, the canning and the water together with void and water density profiles, all stored as 12-bit integers in the digital machine.

The latest investigations of the void production carried out by the static program show that the dynamic void calculations are inadequate, but also without importance in the working range for the dynamic model. The void mechanism should be further studied and the model improved, or the void representation should be completely omitted. The data for the function f_v given in appendix B are consequently arbitrary and not based on static calculations.

The analog diagram is given in appendix B together with scaled equations, DFG tables and potentiometer lists. Suppressed zero-points are used in order to improve the signal resolution in the AD/DA conversion. The zeropoints are:

T_u : 800 °C

T_{ca} : 300 °C

T_c : 300 °C

ρ_m : 500 kg/m^3.

The scale factors and the corresponding working ranges are:

SF N = 1/500	Range:	0-500 MW/section
SF Q_u, SF Q_c = SF N		
SF T_u = 1/500	Range:	800 ± 500 °C
SF T_{ca} = 1/100	Range:	300 ± 100 °C
SF T_c = 1/50	" :	300 ± 50 °C
SF α = 10	" :	0-0.1
SF ρ_m = 1/500	:	500 ± 500 kg/m^3

SF c_p = 100	Range:	0-0.010 MJ/kg°C
SF$(1/\lambda_u)$=2 E-6	" for λ:	(2-5)E-6 MW/m°C
SF W_c = 1/15000	" :	5000-15000 kg/s

Other scale factors for intermediate variables may be found in the list of scaled equations.

The digital routine, HYDRA1, that controls the calculations is found in file PWR.8B, appendix A. The routine uses 3 internal subroutines: HIC, OPDA and TRVENT, and one library subroutine, DIVI. HYDRA1 links directly to the next routine HYDRA2, which is discussed in section 4.2.

The computing sequence for a core section consists of 3 steps. First, the old outlet values are set on analog output channels and MDACs, while track-store amplifiers fetch the new inlet values to the section in question. Second, the computing circuit is switched to the computing mode to find the new set of outlet values; during the amplifier transients the digital machine is used to update the stored values for the previous section. Third, the changes for the new outlet values are read into the digital machine, and the computing circuits are switched to store and track mode. The first core section requires a special subroutine, HIC, for initialization. At the end the hybrid routine is used one extra time to convert the heat stored in steam to an increased water temperature.

The computation is controlled via the digital outputs DO(0) - DO(3) and the digital input DI(1), as shown in the diagram for the logic units. The "ic" signal is used to insert the inlet variables T_{ci} and α(o) = 0; "co" sets the track-store units in compute mode; the "ho" impulse shifts the section outlet value on one track-store amplifier to the inlet value on the other track-store amplifier. The "rs" signal is used to shift between the analog signals (Q_c-Q_b) and ΣQ_b sent out from PDP8 for the last section. The two pulses t_1 and t_2 can be used to control track-store amplifiers to sample and hold any signal for a selected section. The selection is done with the preset knobs for the counters BCD0 and BCD1.

Some scale factor dependent numbers are distributed among the routines. These are all parameters for JMS DIVI:

HYDRA1:

HL + 21 lines: $(SF\ Q_k)/(SF\ \Sigma Q_k) = 10 = 12_8$

\+ 9 " : $(SF\ \Delta_t T_c)/(SF\ T_c) = 50/10 = 5$

OPDA:

line 11: $(SF\ \Delta_t T_u)/(SF\ T_u) = 500/25 = 20 = 24_8$

\+ 5 lines: $(SF\ \Delta_t T_{ca})/(SF\ T_{ca}) = 100/25 = 4$

\+ 5 lines: $(SF\ \Delta_t T_c)/(SF\ T_c) = 50/10 = 5$

\+ 10 lines: $(SF\ \Delta\alpha)/(2 \times SF\ \alpha) = 100/20 = 5$

\+ 11 lines: $(SF\ Q_k)/(SF\ \Sigma Q_k) = 500/50 = 10 = 12_8$

The variables T_u, T_{ca}, T_c, α and ρ are stored in the arrays A0-A15 as the first 5 elements. Element no. 6 is used for boron acid concentration, no. 7 for regulating rod density and no. 8 contains an index pointer with the array numbers from 0 to 15. The arrays are found in the last file page in file PWR.8B.

The communication between the two machines goes through the following units:

AI0 : $(Q_b/50)$

AI1 : $-(\Delta_t T_u/25)$

AI2 : $(\Delta_t T_{ca}/25)$

AI3 : $(\Delta_t T_c/10)$

AI4 : $(100\ \Delta_t \alpha)$

AI5 : $-((\rho_m-500)/500)$

AO1 : $-(\Delta T_u/500)_n$

AO2 : $(\Delta T_{ca}/100)_n$

AO3 : $(\Delta T_c/50)_n$

AO5 : $(\Delta T_c/50)_{inlet}$ or $(\Sigma Q_b/500)$

MDAC0: $(N/500)_n$

MDAC1: $(10\ \alpha)_n$

4.2. Heat transport in the primary circuit

The primary loop is divided into the following compartments:

Reactor upper plenum	46.00 m^3
3 tube sections of	1.177 "
SG inlet chamber	4.57 "
2 SG U-tube sections of	10.45 "
SG outlet chamber	4.57 "
2 tube sections of	1.230 "
3 tube sections of	1.173 "
2 reactor downcomer sections of	6.625 "
reactor lower plenum	23.75 "

Only two physical quantities are needed and they are both used as constant values: $\rho_f = 725\ kg/m^3$ and $\frac{d\rho_f}{dT}$, which is evaluated at 3 temperature levels: 285, 300 and 318 ^oC giving -1.80, -2.10, -2.60 $kg/m^{3o}C$ respectively.

The calculations are carried out in the digital routine FPP2 which is found in file PWR2.8B. The routine calculates in addition some steam generator parameters and links to the turbine power calculation. It is activated in the PDP8 routine HYDRA2 after insertion of input variables which are:

AI : $(W_c/15000)$

AI14 : $(W_p/5000)$

AI10 : $((T_{po}-300)/50)$

The temperature calculations are made strictly according to the formulae (4.11) - (4.13). The sum term $\Sigma\Delta_t T_c$ in (4.13) is calculated in the routine HYDRA1 and transferred to FPP2.

Convertion of the reactor lower plenum temperature to fixed form may result in overflow announced by the message TRAP6 20. The reactor upper plenum temperature is sent out at MDAC 14 as $((T_{up}-250)/100)$.

The first file page in file PWR2.8B contains some numerical data which are:

Array VPL: The volumes as listed above [illegible]

VC : 1 core section volume = 1.[illegible]

SFWC : 1/(2048 × SF WC) = [illegible]

SFWP : 1/(2048 × SF WP) [illegible]

SFTIN	: 1/(2048 × SF T)	= 50/2048	= 0.0244141
SFTUD	: 2048 × SF T	= 2048/50	= 40.96
FDT	: Δt		= 0.1
FROK	: ρ_f		= 725
DRODTM	: $\frac{d\rho_f}{dt}$ at 300 °C		= -2.10
DRODTH	: " " 318 °C		= -2.60
DRODTL	: " " 285 °C		= -1.80

The array TPL contains the temperature belonging to the volumes in VPL with an extra element for the outlet temperature T_{po} from the steam generator U-tubes.

4.3. Boron acid distribution

2 tube sections of (the first is the insertion point for boron acid)	1.173 m^3
2 reactor downcomer sections	6.625 "
Reactor lower plenum	23.75 "
4 reactor core sections of	3.54 "
Reactor upper plenum	46.00 "
3 tube sections of	1.177 "
SG inlet chamber	4.57 "
4 SG U-tube sections of	5.225 "
SG outlet chamber	4.57 "
2 tube sections of	1.230 "
1 tube section of	1.173 "

The calculations are carried out in the routine HYDRA3 in file PWR.8B. It follows directly after HYDRA2 mentioned in the previous section.

In order to save time for the floating point processor, fixed point arithmetic is used. The boron acid concentration is represented by 12-bit positive integers for the range 0-0.002

(0-2000 ppm) giving a scale factor SF C_b = 500. With SF W_b = 1 eq. (4.14) scaled in machine units becomes:

$$[500C_b(o,n+1)] =$$

$$\left([500C_b(o,n)] + \frac{\Delta tW}{V\,\rho_f}\left([500C_b(i,n+1)] + 0.1\frac{(W_b)/V}{(\frac{\rho}{5000})}\right)\right)/N$$

$$N = 1 + \frac{\Delta tW}{V\,\rho_f}$$

Changing to the internal number representation and the unit ppm for boron acid concentration with 2000 ppm equal to the integer 4096 gives:

$$\{2.048\ C_b(o,n+1)\} = (1024\{2.048\ C_b(o,n)\} + \{1024\frac{\Delta tW}{V\,\rho_f}\} \times$$

$$(\{2.048\ C_b(i,n+1)\} + 409.6\frac{(W_b)/V}{(\frac{\rho}{5000})}))/N$$

$$N = 1024 + \{1024\frac{\Delta tW}{V\,\rho_f}\}$$

with $\{1024\frac{\Delta tW}{V\,\rho_f}\} = 69\frac{\{2048(\frac{W_p}{5000})\}}{\{200\ V\}}$

for the primary circuit outside the reactor,

and $\{1024\frac{\Delta tW}{V\,\rho_f}\} = 69\frac{\{2048(\frac{W_c}{15000})\}}{\{66.67\ V\}}$

for the volumes inside the reactor. The density ρ_f is taken as the constant value 725 kg/m^3. The equation can be transformed to

$$\{2.048\ C_b(o,n+1)\} = \{2.048\ C_b(o,n)\} + \{1024\frac{\Delta tW}{V\,\rho_f}\} \times$$

$$\left(\{2.048\ C_b(i,n+1)\} - \{2.048\ C_b(o,n)\} + 409.6\ \frac{\{2048\ W_b\}}{[illegible]}\right)/[illegible]$$

The last term with W_b is only present in the [illegible] the boron acid insertion compartment. The [illegible] equation is valid for a power station with 3 primary loops with equal coolant flow and with boron acid insertion in all loops. With only one insertion point the constant 409.6 is reduced to 409.6/3, if the maximum insertion rate remains 1 kg/s for that point.

The last equation is the final form for programming.

The calculation routine HYDRA3 contains an array VBO with volume values equal to {200 V} outside the reactor and {66.67 V} inside.

VBO: 235; 235; 1583; 236; 236; 236; 236; 3067; 235; 235; 235;
914; 1045; 1045; 1045; 1045; 914; 246; 246; 235.

The array for the boron acid concentration, CBO, is found in the last file page together with the array CBREST used for accumulated remainder storage. The concentrations are further inserted in the 16 arrays A0-A15 using one compartment over 4 core sections.

The inlet flow of boron acid W_b goes through AI8. The concentration in the mixing compartment is sent out on MDAC9 with scale factor SF C_b = 1/2000 with ppm as unit.

5. THE PRESSURISER MODEL

Basic data:

Height, inner	11.27	m
Diameter, inner	2.135	m
Volume:	37.8	m^3
Normal water volume:	22.0	m^3
Steam-tank surface:	39.0	m^2
Surge tube:		
Length	13.0	m
Diameter, inner	284.2	mm
Volume	0.825	m^3

5.1. The two-point non-linear model

Physical parameters

ρ_{fs} = (-4.79928E-3 × p - 0.426907) × p + 775.435

ρ_{fs} = (5.83223E-3×p-o.684103)×p+67.9603

$\frac{d\rho_{fs}}{dp_s}$ = ((-2.82339E-6×p+1.06286E-3)×p-0.135616)×p+4.1627

$\frac{d\rho_{gs}}{dp_s}$ = ((1.94994E-6×p-7.23306E-4)×p+9.55994E-2)×p-3.63699

h_{fs} = (2.36941E-6×p+3.34697E-3)×p+1.05577

h_{gs} = (-1.55610E-5×p+1.72963E-3)×p+2.705997

$\frac{dh_{fs}}{dp_s}$ = (2.52025E-7×p-7.1493E-5)×p+9.0087E-3

$\frac{dh_{gs}}{dp_s}$ = ((-3.76728E-9×p+1.42818E-6)×p-0.202486E-3)×p+8.11117E-3

$(\frac{\partial\rho_f}{\partial h})_p$ = (-1.55056E3×h_f+4.16825E3)×h_f-3.20438E3

$(\frac{\partial\rho_f}{\partial p})_h$ = 0.25

$(\frac{\partial\rho_g}{\partial h})_p$ = 0.61E3×h_g-1.74E3

$(\frac{\partial\rho_g}{\partial p})_h$ = -0.7×h_g+2.49

c_{pg} = 0.010 MJ/kg°C for steam near saturation

$\frac{dT_s}{dp_s}$ = 0.60 °C/bar for saturated steam

C_v = 10 MJ/°C for the tank wall in [illegible]

k_{qgv} = 0.2 MJ/°C for the steam-tank [illegible]

h_{fg} = h_{gs} - h_{fs} [illegible]

$$\rho_f = \rho_{fs} + \frac{\partial \rho_f}{\partial h} (h_f - h_{fs})$$

$$\rho_g = \rho_{gs} + \frac{\partial \rho_g}{\partial h} (h_g - h_{gs})$$

The units are: ρ : kg/m^3

h : MJ/kg

p : bar

Input parameters:

h_k = 1.23 MJ/kg

h_i = 1.45 "

The program is given in appendix H. It is written in the macro language HYBAL for communication with the analog machine and contains 4 FPP-routines and 1 PDP8-code routine.

The PDP8-code routine controls the FPP-routines and takes care of the analog output setting.

FST is a parameter input routine. It may at any time be requested by typing "0" (zero) at the DEC-writer. It must be called once, when the program is started. It is used to define IC values for VF, P, and Q, and further to insert control parameters for Q, WK and WR as used in equations (5.1.8)-(5.1.10).

INPUT is an actuation signal input routine. It follows automatically after FST and may, besides, at any time be called from the DEC-writer by typing "1". It is used to define the input variable ΔW_i as either a step- or a ramp-pulse function. DELTA WI = impulse height, DELTA T = impulse width, and STEPSWITCH = 1 gives a step, while STEPSWITCH = 0 gives a ramp-pulse.

FIC is an IC insertion routine; it resets the variables to the values specified in FST and prepares for a transient calculation.

FOP is the main transient calculation routine.

The operation of the program is controlled via the digital inputs DI(0), DI(1) and DI(2). For DI(0) = 1 the program goes to the IC-mode; for DI(0) = 0 and DI(1) = 1 it goes to the operate mode, for which the calculations are synchronized via pulses (100 μ sec.) on DI(2). As the integration step is 0.1 sec., 10 pulses/sec give real time calculation. A pulse rate of 100 per sec.

may be used to speed up the calculations for slow transients, but 10 pulses/sec. is recommended for short fast transients due to an iterations loop, which is interrupted by the synchronization pulse. 100 pulses/sec. give only time for 2 runs through the loop, resulting in damped oscillations in the time derivative $\dot{p}$ for step input function.

All output goes through analog channels according to the following list with variables, scale factors, zeropoints and TRAP6 numbers at overflow:

A00: $[(p-p_o)/20]$	TRAP6	0
A01: $[(V_f-V_{fo})/10]$	"	1
A02: $[W_e/50]$	"	2
A03: $[W_c/50]$	"	3
A04: $[W_k/50]$	"	4
A05: $[W_r/100]$	"	5
A06: $[Q/2]$	"	6
A07: $[\dot{p}/2]$	"	7

The conditions of the water and steam phases are shown by digital outputs. DO(0) = 1 indicates water saturation, and DO(1) = indicates steam saturation.

The program contains the following constants:

DT = Δt = 0.1

V = 37.8 Tank volume

HWK = h_k = 1.23

HWI = h_i = 1.45

KRFS: constants for ρ_{fs}

KRGS: " " ρ_{gs}

KRFSP: constants for $\frac{d\rho_{fs}}{dp_s}$

KRGSP: " " $\frac{d\rho_{gs}}{dp_s}$

KHFS: " " h_{fs}

KHGS: " " h_{gs}

KHFSP: " " $\frac{dh_{fs}}{dp_s}$

KHGSP: constants for $\frac{dh_{gs}}{dp_s}$

KRFH: " " $(\frac{\partial\rho_f}{\partial h})_p$

KRGH: " " $(\frac{\partial\rho_g}{\partial h})_p$

KRGP: " " $(\frac{\partial\rho_g}{\partial p})_h$

RFP $= (\frac{\partial\rho_f}{\partial p})_h$

CPG $= c_{pg} = 0.01$

DTSP $= \frac{dT_s}{dp_s} = 0.6$

CV $= C_v = 10$

KQGV $= k_{qgv} = 0.2$

SP $= 2048 \times SF\ p_p = 2048/20 = 102.4$

SVF $= 2048 \times SF\ V_f = 2048/10 = 204.8$

SWE $= 2048 \times SF\ W_e = 2048/50 = 40.96$

SWC $= 2048 \times SF\ W_c = 2048/50 = 40.96$

SWK $= 2048 \times SF\ W_k = 2048/25 = 81.92$

SWR $= 2048 \times SF\ W_r = 2048/100 = 20.48$

SQ $= 2048 \times SF\ Q = 2048/2 = 1024$

SPP $= 2048 \times SF\ \dot{p} = 2048/2 = 1024$

5.2. The simplified pressuriser model

The physical parameters are represented by polynomials of lower degree than used in section 5.1 to save computing time.

$\rho_{fs} = 602 - 1.82\times(p-150) = 875 - 1.82\times p$

$\rho_{gs} = 98 + 1.04\times(p-150) = -58 + 1.04\times p$

$\frac{d\rho_{fs}}{dp_s} = -(1.82 + 0.0092\times(p-150)) = -(0.44 + 0.0092\times p)$

$\frac{d\rho_{gs}}{dp_s} = 1.04 + 0.0112\times(p-150) = -0.64 + 0.0112\times p$

$h_{fs} = 1.611 + 0.0040\times(p-150) = 1.011 + 0.0040\times p$

$h_{gs} = 2.614 - 0.0029\times(p-150) = 3.049 - 0.0029\times p$

$\frac{dh_{fs}}{dp_s} = 4.0\ E{-3}$

$\frac{dh_{gs}}{dp_s} = -(2.90 + 0.030\times(p-150))\ E{-3} = (1.6 - 0.030\times p)\ E{-3}$

$(\frac{\partial\rho_f}{\partial h})_p = -(525 + 730\times(h_f-1.6)) = 643 - 730\times h_f$

$(\frac{d\rho_f}{dp})_h = 0.25$

$h_f(W_i) = 1.395 + 0.593E{-2}\times(T-310) = -0.4433 + 0.593E{-2}\times T$

$h_f(W_k) = 1.235 + 0.504E{-2}\times(T-280) = -0.1762 + 0.504E{-2}\times T$

$T_{sa} = 0.54 \times (p-150) + 324.1 = 261.1 + 0.54 \times p$

The program is given in appendix A, file PWR2.8B, file pages 2 and 3. File page 2 contains all the numerical data and variables, and file page 3 contains the calculation routine consisting of an IC-routine, PRIC, and an OP-routine, PROP.

The IC values and control parameters are inserted as fixed data. The input variables ΔW_i, T_i and T_k are received from the routine FPP2 discussed in section 4.2. The surge flow ΔW_i is added to the steady state flow $W_i(0)$ calculated in the IC routine. For long-term transients a control term, $\Delta W_i(c)$, is necessary to keep the water level at a fixed steady state value; it is not included in the present version. The temperatures T_i and T_k of the surge flow and the cooling water are used to calculate the corresponding enthalpy values.

The only output value needed by other submodels is the saturation temperature T_{ps} calculated from the pressure. But other variables are displayed too for operator communication. The output variables with scale factors, zeropoints and overflow [illegible] numbers are:

A00 :	$((p_p-150)/20)$	TRAP6	40
MDAC10:	$((V_f-12)/20)$	"	41
MDAC11:	$(W_e/50)$	"	42
MDAC12:	$(W_c/50)$	"	43
MDAC7 :	$((T_{ps}-300)/100)$	"	44

The iteration mentioned for the more detailed model is not necessary here, as the driving function W_i has no high frequency components, and the computing time would be unacceptably long too. But there still exists a tendency for oscillations to start, when the water condition shifts between the two states. This is avoided using a digital filter for W_e with a time lag of 0.2 sec.

The constants in the first file page are:

DT = Δt = 0.1

VPR = 37.8 Tank volume

KPP : coefficients for the polynomials:

$$\rho_{fs},\ \rho_{gs},\ \frac{d\rho_{fs}}{dP_s},\ \frac{d\rho_{gs}}{dP_s},\ h_{fs},\ h_{gs},\ \frac{dh_{gs}}{dp_s},\ \left(\frac{d\rho_f}{dh}\right)_p, h_i,\ h_k$$

and $\frac{dT_s}{dp_s}$

HFSP= $\frac{dh_{fs}}{dp_s}$ = 4.0E-3

RFP = $\left(\frac{\partial\rho_f}{\partial p}\right)_h$ = 0.25

WIKO= $\frac{\Delta t}{\rho_f \times (V_{\text{surge tube}})/3} = \frac{3 \times 0.1}{725 \times 0.825}$ = 0.502E-3

SP = 2048 × SF p_p = 2048/20 = 102.4

SVF = 4096 × SF V_f = 4096/20 = 204.8

SWE = 4096 × SF W_e = 4096/50 = 81.92

SWC = 4096 × SF W_c = 4096/50 = 81.92

STSA= 4096 × SF T_{ps}= 4096/100= 40.96

NVF = Zeropoint for V_f = 12

VFØ = IC value for V_f

PØ = " " " p

QØ : Control parameters for Q:

IC value = 0.038 MW

Offset = 1 bar

Gain = 0.16 MW/bar

Max.value= 1.3 MW

WKØ : Control parameters for W_k:

IC value: calculated in the PRIC routine

Offset = 1 bar

Gain = 2 kg/s/bar

Max.value= 20 kg/s

WRD : Control parameters for W_r:

Offset = 10 bar

Max.value= 100 kg/s

6. THE STEAM GENERATOR

Basic data:

A_p = 1.035 m^2

A_s = 5.160 "

A_r = 4.630 "

A_b = 9.770 "

A_d = 0.687 "

De_p = 0.0197 m

De_s = 0.0436 "

De_d = 0.136 "

Δr = 0.00127 m

V_p = 20.9 m^3

V_s = 52.2 "

V_e = 75.0 "

V_r = 12.6 "

V_{bl} = 18.8 "

V_{bh} = 7.8 "

V_d = 6.94 "

V_{pi} = V_{po} = 4.57 m^3

L_c = L_d = 10.11 m

L_r = L_b = 2.725 "

Δx = Δz = 0.5055 m

O_p = 210 m^2/m

O_s = 237 "

O_r = 223 "

λ_r = 0.014 KW/m^oC

C_r = 980 KJ/m^oC

S = 1.5

Δt = o.05 s

<u>6.1. The detailed one-dimensional model</u>

<u>Physical parameters:</u>

$$T_{sa} = 137.88 + 5.0121 \times p - 0.79614E\text{-}1 \times p^2 + 0.72476E\text{-}3 \times p^3 - 0.25717E\text{-}5 \times p^4$$

$$\rho_{fs} = 922.02 + 0.54104 \times T_{sa} - 0.41904E\text{-}2 \times T_{sa}^2$$

$$\rho_{gs} = -104.953 + 1.53481 \times T_{sa} - 0.768233E\text{-}2 \times T_{sa}^2 + 0.141607E\text{-}4 \times T_{sa}^3$$

$$\frac{d\rho_{fs}}{dp_s} = -33.314 + 0.29584 \times T_{sa} - 0.93865E\text{-}3 \times T_{sa}^2 + 0.10129E\text{-}5 \times T_{sa}^3$$

$$\frac{d\rho_{gs}}{dp_s} = 1.0923 - 0.59817E\text{-}2 \times T_{sa} + 0.14787E\text{-}4 \times T_{sa}^2$$

$$h_{fg} = 1.9912 + 3.2023E\text{-}3 \times T_{sa} - 0.17199E\text{-}4 \times T_{sa}^2$$

$$\frac{dh_{fs}}{dp_s} = 0.18065 - 1.7121E\text{-}3 \times T_{sa} + 0.56767E\text{-}5 \times T_{sa}^2 - 0.64176E\text{-}8 \times T_{sa}^3$$

$$\frac{dh_{gs}}{dp_s} = 0.064714 - 0.63723E\text{-}3 \times T_{sa} + 0.20824E\text{-}5 \times T_{sa}^2 - 0.23142E\text{-}8 \times T_{sa}^2$$

$$c_{pp} = -0.042044 + 0.20448E\text{-}3 \times T_p + 0.77403E\text{-}6 \times T_p^2 - 0.28309E\text{-}8 \times T_p^3 - 0.87750E\text{-}11 \times T_p^4 + 0.26327E\text{-}13 \times T_p^5$$

$$c_{ps} = 0.22556E\text{-}3 + 0.61417E\text{-}4 \times T_{sa} - 0.31531E\text{-}6 \times T_{sa}^2 + 0.57419E\text{-}9 \times T_{sa}^3$$

$$H_p = 1.82569 - 0.772876E\text{-}2 \times T_p + 0.155828E\text{-}4 \times T_p^2$$

$$H_s = 0.875 + 0.0012 \times (T_{sa} - 250)$$

$$\rho_f = 1740.9 - 9.4540 \times T_p + 0.036496 \times T_p^2 - 0.54202E\text{-}4 \times T_p^3$$

The units are m^3, kg, bar and MJ except for H_p and H_s where KJ is used instead of MJ.

The program, which is written in Fortran IV, is given in Appendix J. It uses 3 device numbers, which must be defined when it is started.

Device no. 7 is the normal output device for the transients. DEC-writer, lineprinter, DEC-tape or disc file may be used.

Device no. 6 is the output device for a new set of IC-values calculated by the program itself. Paper tape, DEC-tape or disc file may be used.

Device no. 5 is the input device for the IC-values needed at start. Paper tape, DEC-tape or disc file may be used.

Device nos. 7 and 5 must always be defined, while a definition for no. 6 is only needed when a new IC-value set is produced. No. 7 is used with option C for a non-file-structured device, such as the DEC-writer, and without option C for a file-structured device.

At program start the operator must type some input variables and parameters on request; these are:

WP : W_p, primary flow

CL : C_1, steam valve constant

TPI : T_{pi}, primary inlet temperature

TFI : T_{fi}, feedwater temperature

NT : Step/ramp indicator. NT = 0 gives a step input; NT = n gives a ramp input of length $n \cdot \Delta t$. The input step or ramp may be in any of the 4 variables mentioned above.

M : number of printouts in a transient.

N : number of time intervals Δt between printouts.

It is a good practice to use the same input values as in the IC values for 1 or 2 printouts to check that the IC-conditions are really in a stationary state, and then return to the input section by the following program control facility.

After the last printout, after $(N \times M \times \Delta t)$ sec. problem time, the program asks for a continuation input switch:

1. Stop the program.
2. Start with new input variables.
3. Continue the transient calculation with new values of M and N.
4. Write a new set of IC values on the output file specified by the start.
5. Type a profile table on device no. 7.

An example of the output is given in appendix J. It is shown how the program is started and the different control switches are used. The profile printout contain 8 columns with a line for each core section, so 2 columns are used for T_p, T_{r1} and T_{r2}. The extra lines for T_s and T_p give the inlet temperatures and the temperature in the primary inlet and outlet chamber.

The calculation time is about 15 sec. for 1 sec. problem time.

The program contains a head with DATA specifications of main parameters. These are:

AS = A_s	AP = A_p	AR = A_r	AF = A_b	AD = A_d
LC = L_c	LR = L_r	LF = L_b	DZ = Δz	
OS = O_s	OP = O_p	OR = O_r		
VR = V_r	VE = V_e	VFL = V_{bl}	VFH = V_{bh}	
VDO = V_d	VPI = V_{pi} = V_{po}			
DEP = D_{ep}	DES = D_{es}	DED = D_{ed}	DR = Δr	
GH = $g \times \Delta x$	CRH = $C_r/2$	LAR = λ_r	CPR = c_{pm}/c_{ps}	
S = S	DT = Δt			

6.2. The simplified steam generator model

The basic data are the same as for the detailed model, but several physical data are used as constant values. The simplifications and consequences are most conveniently discussed for each equation separately, as the same parameter may have quite different influence in two equations. All the equations are given with numerical values, those containing only basic data without comments.

Eq. (6.2.1a): $\rho_f = 725\ kg/m^3$. Variations only have influence on a time lag, while variations in c_{pp} have a strong influence on the heat delivery to the secondary side. Therefore a temperature dependent representation of c_{pp} is important:

$$c_{pp} = 0.026285 - 0.16617E\text{-}3 \times T_p + 0.32291E\text{-}6 \times T_p^2$$

$$\dot{\Delta T}_{po} = 0.660E\text{-}4 \times \left(\frac{Q_p}{c_{pp}} - W_p \Delta T_{po}\right). \qquad (6.2.1a)$$

$$T_{po} = T_{p1,n} - \Delta T_{po}. \qquad (6.2.1)$$

Eqs. (6.2.1b) and (6.2.1c) are included in the calculations of the primary loop temperature as described in section 4.2.

Eq. (6.2.2): $a_p = 0.41$

$$T_p = 0.41 T_{p1} + 0.59 T_{po}. \qquad (6.2.2)$$

$$\dot{T}_{r1} = 0.1009(Q_p - Q_r). \qquad (6.2.3)$$

$$\dot{T}_{r2} = 0.1009(Q_r - Q_s). \qquad (6.2.4)$$

Eq. (6.2.5): The heat transfer parameter H_p is equal to 0.92 ± 0.03 in the temperature range $300 \pm 20\ ^oC$ so it is used with the constant value 0.92

$$Q_p = 0.1917 W_p^{0.8}(T_p - T_{r1}). \qquad (6.2.5)$$

$$Q_r = 49.71(T_{r1} - T_{r2}) \qquad (6.2.6)$$

Eq. (6.2.7): The term exp(p/43.4) will vary in the range [illegible], but as the temperature difference $(T_{r2} - T_{se})^2$ is any case is small due to the quadratic term, it is [illegible] to set (p/43.4) equal to 4.6. The error in [illegible] for the greatest pressure deviation, which is regarded as insignificant compared to the variation in saturation temperature over the range 260 - 290 °C.

$$Q_s = 42.53(T_{r2} - T_{ss})^2. \qquad (6.2.7)$$

Eq. (6.2.8): $c_{ps} = 0.0052$ MJ/kg°C with an error less than 10%. The influence on Q_k will be much smaller as the second term is only about 10% of Q_s.

$$Q_k = Q_s - 0.0052\ W_s(T_{ss} - T_d) \qquad (6.2.8)$$

Eqs. (6.2.9): The equation has 3 parameters dependent on temperature and load, as the total coefficient to $\dot{p}$ is regarded as one parameter. ρ_{gs} varies in the range 25 - 40 kg/m³, but is used as a constant equal to 33 kg/m³, because it only has influence on the time constant for V_g, which anyway is small compared with the dominating time constant for the total system. h_{fg} as coefficient for Q_k is rather important, as it determines the steady-state value of the steam production when Q_k is given; so a second degree polynomial is used:

$$h_{fg} = 1.9912 + 0.32023E{-}2 \times T_{ss} - 0.17199E{-}6 \times T_{ss}^2 .$$

The coefficient D for $\dot{p}$:

$$D = \frac{1}{h_{fg}} \left(V_g\left(\rho_{gs} \frac{dh_{gs}}{dp_s} + h_{fg} \frac{d\rho_{gs}}{dp_s}\right) + V_f\ \rho_{fs} \frac{dh_{fs}}{dp_s} - V_s\right)$$

has been calculated for several steady-state load levels using results obtained by the detailed program. The coefficient is included in table C.2 in appendix C. It appears to be fairly constant in the load range 25 - 115% of full load. For a transient state it may run outside the range 90 - 108 kg/bar shown in the table, but it is still used as a constant equal to 98 based on the same argumentation as used above for ρ_{gs}.

$$\dot{V}_g = 0.33\left(\frac{Q_k}{h_{fg}} - 98\dot{p}_s - W_g\right) \qquad (6.2.9)$$

or normalized with respect to V_s:

$$\frac{\dot{V}_g}{V_s} = \dot{U} = 0.580E{-}3 \times \frac{Q_k}{h_{fg}} - 0.0570\dot{p}_s - 0.58E{-}3 \times W_g . \qquad (6.2.9)$$

Eq. (6.2.10): The coefficient $(\rho_{fs} - \rho_{gs})$ varies in the range 690 - 760 kg/m³, so a constant value equal to 725 kg/m³ is used. The coefficient E:

$$E = V_g \frac{d\rho_{gs}}{dp_s} + V_f \frac{d\rho_{fs}}{dp_s}$$

is shown in the table C.2. The working range appears to be -(40 - 70) kg/bar. Even the variation is quite large, the same argumentation as used above for ρ_{gs} justifies the selection of a constant value of 52 kg/bar.

$$W_f = W_s - W_g + 725\dot{V}_g + 52\dot{p}_s \qquad (6.2.10)$$

or normalized with respect to V_s:

$$W_f = W_s - W_g + 37800\dot{U} + 52\dot{p}_s . \qquad (6.2.10)$$

Eq. (6.2.11): ρ_{gs}/ρ_{fs} is important for the determination of the void fraction α, so a second-degree polynomial is used.

$$10\frac{\rho_{gs}}{\rho_{fs}} = 0.14201E{-}2 + 0.51861E{-}2 \times p_s + 0.26371E{-}4 \times p_s^2 .$$

The slip ratio S is used as a constant 1.5, as for the detailed model.

$$W_g = 1.5\ W_f \frac{\alpha}{1-\alpha} \frac{\rho_{gs}}{\rho_{fs}} . \qquad (6.2.11)$$

Eq. (6.2.12): The function $F_\alpha(V_g)$ is shown in the table C.2 and plotted in Ref. 1, fig. 12. A straight line gives a reasonable representation of the calculated values.

$$\alpha = \left(2.33 - 1.74\frac{V_g}{V_s}\right)\frac{V_g}{V_s} . \qquad (6.2.12)$$

Eqs. (6.2.13) - 6.2.16): The steam transit [illegible] between 0.5 and 1.5 sec. according to the table C.2. [illegible] appears as a dynamic correction term for $\dot{p}$ and W_b, a constant value of 1.0 sec. will be used. From the table the working range for C1 is found to be 27 - 30 kg/bar, which justifies the selection of a constant value of 28 kg/bar. The denominator in eq. (6.2.15) is given as C2 in the table C.2. It varies in the range 73 - 78 kg/bar, so a constant value equal to 75 is reasonable. Finally, ρ_{fs} and ρ_{gs}, in connection with V_r in eqs. (6.2.15) and (6.2.16), are taken as constants: ρ_{fs} = 750 and ρ_{gs} = 33 kg/s.

$$\dot{\alpha}_r = \alpha - \alpha_r \qquad (6.2.14)$$

$$\dot{p}_s = (W_g - W_1 - 416\dot{\alpha}_r)/75 \qquad (6.2.15)$$

$$W_b = W_f + 28\dot{p}_s + 9450\dot{\alpha}_r \qquad (6.2.16)$$

<u>Eqs. (6.2.17) and (6.2.18):</u> ρ_{fs} = 750 kg/s and c_{pm}/c_{ps} = 0.94.

$$\dot{T}_b = 0.709E\text{-}4\times(W_b(T_{ss} + T_b) - 0.94\ W_i(T_b - T_i)) \qquad (6.2.17)$$

$$\dot{T}_d = 1.921E\text{-}4\times W_s(T_b - T_d) \qquad (6.2.18)$$

<u>Eqs. (6.2.19) - (6.2.21):</u> F_f = 0.0425. The function $F_R(V_g)$ is tabulated in table C.2 and plotted in Ref. 1, fig. 12. In the working range the straight line $F_R = 77\ V_g/V_s$ is a usable approximation even though the curve must end in $\Sigma R\Delta x = L_c$ = 10.11 for V_g = 0. $\Sigma L_x A_c/A_x$ = 12.1 and $V_{fi} = V_d A_d/A_s$

$$\frac{\Delta p_1}{\rho_{fs}} = 0.341\ \frac{V_g}{V_s} v_d^{1.8} \qquad (6.2.19)$$

$$\frac{\Delta p_2}{\rho_{fs}} = 0.866\ v_d^{1.8} \qquad (6.2.20)$$

$$\dot{v}_d = 0.0826(99.34\ \frac{V_g}{V_s} - (\frac{\Delta p_1}{\rho_{fs}} + \frac{\Delta p_2}{\rho_{fs}})) \qquad (6.2.21)$$

<u>Eqs. (6.2.22) and (6.2.23):</u> ρ_{fs} = 750 kg/s and the coefficient for $\dot{p}$ is taken as -75 kg/bar, as the variation of ±10% in the working range is without any influence on the other equations.

$$W_s = 515\ V_d \qquad (6.2.22)$$

$$\dot{L}_b = 0.136E\text{-}3\times(W_b + W_i - W_s - 75\dot{p}_s) \qquad (6.2.23)$$

The model is implemented as an analog model with the 3 coefficients c_{pp}, h_{fg} and $(10\ \rho_{gs}/\rho_{fs})$ calculated in a digital routine and inserted via MDACs. The analog diagram is given in appendix C together with the scaled equations, potentiometer listing and DFG tables. Included are also 2 tables which have been used for evaluation of the coefficients. Table C.1 gives some physical parameters in the actual temperature range, and table C.2 gives a set of variables calculated by the detailed model together with some main parameters.

The digital routine for parameter calculation is found in FPP2 together with the primary temperature calculation. The input variables are inserted in the PDP8 routine HYDRA2. These are:

AI12: $[(p_s - 60)/25]$
AI13: $[(T_{ss} - 250)/50]$.

The analog model receives 2 temperatures from the primary temperature routine: T_{p1}, the temperature in the inlet chamber, and $T_{p1,2}$, the temperature in the second of the U-tube compartments. These temperatures are set on analog outputs in the PDP8 routine HYDRA5 together with the adjustment of the MDACs. The output variables with TRAP6 numbers at overflow are:

A06 :	$[(T_{p1} - 300)/50]$	TRAP6	21
A07 :	$[(T_{p1,2} - 300)/50]$	TRAP6	22
MDAC2:	$[0.5759/250\ c_{pp}]$	"	24
MDAC3:	$[0.580/h_{fg}]$	"	25
MDAC4:	$[10\ \rho_{gs}/\rho_{fs}]$	"	26
MDAC13:	$[(T_{p2} - 250)/100]$		

The first file page of PWR2.8B contains some constants belonging to the parameter calculation. These are:

CPPK: coefficients for c_{pp}
HFGK: " " h_{fg}
RGFK: " " $10\ \rho_{gs}/\rho_{fs}$
SFPR: $1/(2048 \times SF\ p_s)$ = 25/2048 = 0.012207
SFTIN: $1/(2048 \times SF\ T)$ = 50/2048 = [illegible]

SFDP4: $4096 \times SF\ (1/c_{pp}) = 4096 \times 0.5759/250 = 9.4355$

SFDP5: $4096 \times SF\ (1/h_{fg}) = 4096 \times 0.580 = 2375.68$

SFDP6: $4096 \times SF\ (10\ \rho_{gs}/\rho_{fs}) = 4096$

SFTUD: $2048 \times SF\ T = 2048/50 = 40.96$

7. THE TURBINE-REHEATER MODEL

Basic data:

Turbine:

$V_h = 10\ m^3$

$V_l = 50\ m^3$

$k_v = 51.30$ kg/s bar

$k_h = 25.95$ kg/s bar

$k_l = 73.50$ kg/s bar

$a_h = 0.138$

$\beta_h = 0.935$

$\beta_l = 0.948$

$\gamma_h = 0.8$

$\gamma_l = 0.8$

$\gamma_g = 0.95$

$\frac{d\rho_g}{dp} = 0.5\ kg/m^3$ bar

Reheater:

Tube dimensions: 22/18 mm

Heating surface = $6000\ m^2$

Tube weight = 80 t

Tube heat capacity $C_t = 33\ MJ/^oC$

Volume outside tube $V_r = 50\ m^3$

Tube heat transfer constant: $45\ MW/^oC$

Heat transfer constant hot side: $45\ MW/^oC$

Heat transfer constant cold side: $11.4\ MW/^oC$

$k_t = 22.5\ MW/^oC$

$k_r = 11.4\ MW/^oC$

$h_{fg} = 1.57$ MJ/kg

c_p for superheated steam = $0.0025\ MJ/kg^oC$

ρ_g " " " $= 5\ kg/m^3$

The pressure dynamics and the reheater equations are implemented as an analog model, while the turbine power calculation is made in a digital routine. The equations for the analog part with numerical values are:

$$\dot{p}_h = 0.20(G_v - G_h) \quad (7.1)$$

$$\dot{p}_l = 0.04(0.862(1 - a_t)G_h - G_l) \quad (7.2)$$

$$G_v = 51.3\ A_v\ p_v\ Y(p_h/p_v) \quad (7.3)$$

$$G_h = 25.95\ p_h \quad (7.4)$$

$$G_l = 73.50\ p_l \quad (7.5)$$

$$T_{tl} = T_{ps} - 2 \quad (7.21)$$

$$Q_t = 22.5(T_{tl} - T_{t2}) \quad (7.22)$$

$$Q_r = 11.4(T_{t2} - T_{ro}) \quad (7.23)$$

$$\dot{T}_{t2} = 0.0303(Q_t - Q_r) \quad (7.24)$$

$$\dot{T}_{ro} = 1.6(Q_r - 0.0025G_r(T_{ro} - T_{ri})) \quad (7.25)$$

$$G_l = G_v + 0.637\ Q_r \quad (7.26)$$

The analog diagram, scaled equation, potentiometer list and DFG table are given in Appendix D. The communication with the digital routine for power calculation is described below.

Turbine power calculations:

The calculations are carried out strictly according to the formulae (7.6) - (7.20) in a digital routine TURB following [illegible] in file PWR.88. The physical parameters are calculated as polynomials as follows:

$$T_s = 87.4263 + 19.8697 \times p_s - 1.8237 \times p_s^2 + 0.955588E\text{-}1 \times p_s^3 - 0.195821E\text{-}2 \times p_s^4 \quad \text{for } 2 < p_s < 17 \text{ bar}$$

$$T_s = 123.752 + 7.14733 \times p_s - 0.182786 \times p_s^2 + 0.270145E\text{-}2 \times p_s^3 - 0.156422E\text{-}4 \times p_s^4 \quad \text{for } 7.5 < p_s < 60 \text{ bar}$$

$$h_{fs} = -83.7618 + 5.55901 \times T_s - 0.785461E\text{-}2 \times T_s^2 + 0.173185E\text{-}4 \times T_s^3$$

$$h_{gs} = 2672.52 - 0.841164 \times T_s + 0.141137E\text{-}1 \times T_s^2 - 0.347827E\text{-}4 \times T_s^3$$

$$s_{fs} = -0.236725E\text{-}1 + 0.153926E\text{-}1 \times T_s - 0.245531E\text{-}4 \times T_s^2 + 0.322284E\text{-}7 \times T_s^3$$

$$s_{gs} = 8.77514 - 0.185358E\text{-}1 \times T_s + 0.460689E\text{-}4 \times T_s^2 - 0.614785E\text{-}7 \times T_s^3$$

The energy unit is here kJ; all the constants and the internal calculations in TURB are in kJ, but the input-output variables are in MW.

The FPP routine TURB receives 3 variables from the analog turbine model via the PDP8 routine HYDRA3. These are:

AI16: $(P_h/100)$

AI17: $(P_1/20)$

AI18: $(Q_r/250)$

The output variables with overflow TRAP6 numbers are:

AO4 : $((T_{ri} - 175)/50)$	TRAP6	32
MDAC6: $(E_g/1000)$	"	31
MDAC5: $\left((1-a_h)(1-a_t)k_h/V_1 \dfrac{d\rho_g}{dp}\right) = (0.8948\ (1-a_t))$	TRAP6	33

T_{ri} and MDAC5 are used in the turbine analog model, while E_g on MDAC6 is used in the power grid analog model.

The TURB routine has a head with the following constants:

GMH : $\gamma_h = 0.8$

GML : $\gamma_l = 0.8$

GMG : $\gamma_g = 0.95$

KHX : $k_h(1-a_h) = 22.369$

SFSC : s_{fs} for condenser = 0.4763

SFGSC: $(s_{gs} - s_{fs})$ for condenser = 7.9197

HFSC : h_{fs} for condenser = 137.77

HFGSC: $(h_{gs} - h_{fs})$ for condenser = 2423.8

KHBH : $k_h\ \beta_h = 24.263$

KLBL : $k_l\ \beta_l = 69.678$

SPH : $1/(2048 \times SF\ p_h) = 100/2048 = 0.048828$

SPL : $1/(2048 \times SF\ p_l) = 20/2048 = 0.0097656$

SQR : $1000/(2048 \times SF\ Q_r) = 1000 \times 250/2048 = 122.07$

SKV : $4096 \times SF\ (1-a_t) = 4096 \times 0.8948 = 3664.92$

SEG : $4096 \times SF\ E_g/1000 = 4096/(1000 \times 1000) = 0.004096$

STRI : $2048 \times SF\ T_{ri} = 2048/50 = 40.96$

NTRI : zeropoint for T_{ri} = 175

KHFS : coefficients for h_{fs}

KHGS : coefficients for h_{gs}

KSFS : coefficients for s_{fs}

KSGS : coefficients for s_{fs}

KTH : coefficients for T_s high pressure

KTL : coefficients for T_s low pressure

C. THE ELECTRICAL POWER GRID

Basic data:

$S_r = 2$

$\tau = 7.5$ s

$\tau_{2v} = 0.25$ s

$\tau_{2t} = 0.5$ s

$E_n = 5000$ MW

E_1 full load = 870

E_2 normal = 4130 MW

$\delta_2 = 0.1$

$k_{e2} = 1\ s^{-1}$

$k_{e1} = 0.004\ MW^{-1}$

Max. valve speeds:

PWR plant turbine: Full stroke in 2.5 s
Base plant turbine: Full stroke in 10 s.

The equations with numerical values are:

$$\frac{\Delta f}{f_n} = \frac{0.5}{1 + 7.5\ s}\frac{\Delta E}{E_n} \tag{8.5}$$

$$\frac{\Delta E_2}{E_2} = \frac{\Delta f}{f_n}(10 + \frac{1}{s})\frac{1}{(1+0.25\ s)(1+0.5\ s)} \tag{8.6}$$

$$\frac{\Delta E}{E_n} = 0.85\frac{\Delta E_2}{E_2} + \frac{\Delta E_1}{5000} + \frac{\Delta E_1}{5000} \tag{8.7}$$

$$A_v = 0.004(E_1 - E_{1r}) \tag{8.8}$$

The analog diagram and potentiometer list are given in appendix E.

9. FILE INPUT-OUTPUT ROUTINES

The routines that perform the input-output functions mentioned in chapter 1 are described here in some detail.

The test routine that is initiated by typing "0" on the DEC-writer is a standard routine from the HYBAL subroutine library SL.FP, so it is not contained in the program listing. It may be used to type and change any floating point number addressed by its octal address. It is not discussed here, as it belongs to the HYBAL library system.

The IC-data output and input routines are built up around the same skeleton. There are two data lists, one for floating point data, ICLIF, and one for 12-bit integers, ICLIH. Both routines have a PDP8-code and a FPP-code section, which transfer data between the core resident program and the disc file PWR.IC according to the two lists. Each list contains a set of specifications consisting of a number followed by an address. The number gives the number of successive data to transfer with the following address as the address of the first data.

The IC output routine has a PDP8-section, ICUD, in file PWR.8B and a FPP-section, ICOUT, in file PWR3.8B. The ICUD routine reads the regulating rod position via AI7, so the reference voltage on the analog machine must be on, when the IC output routine is requested. When finished, the routine gives a message: ICDATA TIL FILE PWR.IC on the DEC-writer.

The IC input routine, which is initiated when DI(11) is set, has a PDP8-section, ICIND, in file PWR.8B and a FPP-section, ICIN, in file PWR3.8B. The routine informs the operator of the regulating rod position and the power reference value, as stored in the IC-data. The ICIND routine adjusts some analog outputs and MDACs according to the IC-data just inserted, and ends with the message: ICDATA IND FRA FILE: PWR.IC.

Reactor static data for new working conditions are inserted from a disc file PWR.ST by the PDP8-routine STAT and the FPP-routine STATF in files PWR.8B and PWR3.8B respectively. File PWR.ST is generated by a Fortran IV program and contains 14 records, the first 13 records with one array each, the last one with 3 numbers. The arrays are: $\emptyset$, N, T_u, T_{ca}, T_c, α, ρ_m, C_1, C_2, C_3, $\Sigma\lambda_n C_n$, CCR (coarse control rod densities) and Σ_a-xenon. The numbers in the last record are regulating rod position and weighting factor, and boron acid concentration. The data is stored in internal code in PWR.ST. The distribution within the core resident program PWR.SV is mainly carried out in the STATF routine, but the final positioning of the regulating rod densities and the boron acid concentration is done in the STAT routine, which also adjusts some analog outputs and MDACs to standard values in order to obtain reasonable start conditions. Further the relative power level is calculated and typed out on the DEC writer together with the regulating rod position. (The full power level is set equal to 2600 MW). The routine ends with the message: [illegible]

FILE PWR.ST.

The logging of variables initiated by typing "3" on the DEC-writer is accomplished by the FPP-routine FLOG in file PWR3.8B. The programming is a straight-forward process, as the data must be handled individually. An output example is given in Appendix L.

The input-output routines contains only few constants that may be changed:

FULL in STAFF: Full reactor power/100

NUF in FLOG: $V_f A/\nu$ = 2.18E-11 for conversion of fission rate to thermal power

KH in FLOG: k_h for the turbine

HFGQR in FLOG: h_{fs} for the turbine reheater

REFERENCES

1. P. la Cour Christensen: Description of the Real Time Power Plant Model PWR-PLASIM, Risø Report No. 318 (1975).
2. DOCKET 50-280, SURRY-1, Final Safety Report.
3. DOCKET RESARA, Vol. 3 & 4.
4. P. Skjerk Christensen: A Static One Dimensional Reactor Model, Risø-M-1774.

APPENDIX A

Digital program listing for the power station model.

```
/        FILE  PWR 8B
/        PWR MODEL  NOV 74
/        PDP8 KODE
/
/        DIGITAL INPUTS
/        BIT0=1  RUN
/        BIT1=1  TRACK 2 ON
/        BIT2=1  PRESSURISER ON
/
         @FINOUT
         @CLEAR
         DCA FPPSI
         CMA,DCA ICIND1
         JMS BIT2
         @PRINT6 OPM
         JMP H1
HEAD.    DIRC
         SPA CLA
         JMP FEJL7          /REGNETID FOR LANG
         JMS BIT2
H1       @TTVC <TTV1.ICUD.STAT.LOG>
         CLA
         DIRC
         SMA
         JMP .+3            /VENT PAA 100 MS SIGNAL
         DIC
         JMP HYDRA1
         CLL RAR
         SZL
         JMP ICIND
         JMP H1
/
TTV1.    FPRST
         RAR
         SZL CLA
         JMP .-3
         DCA FPPSI
         FPICL
         @FPPST:FINOUT.220
         @FPPW:H1
/
BIT2.    0
         CDF 10
         DIR
         AND (1000
         SNA CLA
         JMP .+5
         TAD INS1
         DCA I INSTP
         CDF 0
         JMP I BIT2
         TAD INS2
         JMP .-4
INS1.    JA PROP
INS2.    FEXIT
INSTP.   FPP3EX
/
OPM      @TEXT6:<REMEMBER LIMITERS.MM'S AND SWITCH 0>
/
         PAGE
```

```
/        ROUTINE TIL PWR HYDRAULIK
/
HYDRA1.  CLA                /KLARGOR ADR CELLER
         TAD (N;DCA 10
         TAD (A0+10-1;DCA 11
         TAD (A0+10;DCA 20
         DCA QK
         DCA WIC
         TAD SEKTA;CIA;DCA ST
         CMA;DCA ICI        /1-STIL IC INDIKATOR
/        UDLAES GL.PROFILER:N.TU.TCA.TC.ALFA
HL.      CLA;DPLA;TAD I 10;DPLX
         @ANOUT:1<I 11>
         @ANOUT:2<I 11>
         @ANOUT:3<I 11>
         CLA;DPIA;TAD I 11;DPLX
         ISZ ICI
         JMP .+3
         JMS HIC            /IC INDSTILLING
         JMP .+2
         JMS TRVENT
         DOC                /START COMPUTE PERIODE
         JMS OPDA           /OPDATER GL.VARIABLE
/        INDLAES ANALOG VARIABLE:TU.TCA.TC.ALFA.RO.QK
         @ANINSE:0.6.HJ0
/        COMPUTE STOP
         @DO:2000
/        START TRACK 2
         @DO:3000
         ISZ ST
         JMP HL             /NAESTE SEKTION
         TAD HJ0            /FAERDIG.BEREGN TOPREFLEKTOR TEMP
         JMS DIVI;12
         TAD QK;TAD (4000;AO5W   /QK UD PAA AO5
         @ANOUT:3.A15+2
         CLA;DPDA;DPLX
         DPIA
         JMS TRVENT
         @DO:400
         JMS OPDA
         @ANIN:3
         JMS DIVI;5
         TAD A15+2;DCA A15+2     /TC
         @ANIN:5
         CIA;DCA A15+4           /RO
         @DO:2000
         @DO:3000
         JMP HYDRA2
/
SEKTA.   16                 /SEKTIONSANTAL
ST.      0
HJ0.     ZBLOCK 6
ICI.     0
QK.      0
/
         PAGE
```

```
/        BEREGNING AF PRIMAERKREDS OG DAMPGENERATOR PARAMETRE
/        WELTALSBEREGNING:KONTROLSTANGSTAETHED OG BORKONCENTRATION
/        FPP BEREGNING:TEMP. I PRIMAER KREDS OG
/        DAMPGENERATOR PARAMETRE SAMT TURBINEEFFEKT
/        DATA TIL FPP VIA ARRAY APO:WC.WP.TCU.TPO.TSA.P.WIC
/        DATA TIL FPP VIA ARRAY TBO:P-HIGH.P-LOW.Q-REHEATER
/
/        KLARGOR TIL FPP START.INDLAES:WC.WP.TPO.TSA.P
HYDRA2   @ANIN:6
         SPA
         JMP FEJL0          /WC NEG.
         DCA APO
         TAD APO
         DCA WC
         @ANIN:14
         SPA
         JMP FEJL1          /WP NEG.
         DCA APO+1
         TAD APO+1
         DCA WP
         TAD A15+2          /INDSAET TCU
         DCA APO+2
/        INDLAES TPO.P OG TSA FOR SG
         @ANIN:10
         CIA;DCA APO+3
         @ANIN:11.APO+4
         @ANIN:12.APO+5
         TAD FPPSI
         SNA CLA
         JMP HYDRA2         /INGEN FPPW HVIS FPPSI=0
         [illegible]
/        START FPP BEREGNINGER AF PRIMAER KREDS.DAMPGEN.PARAMETRE
/        [illegible] EFFEKT
[illegible] [illegible].300
/        [illegible] INPUT TIL TURBINEBEREGNINGER
         [illegible]:16.3.TBO
/
/        [illegible] AF NUKLEAR EFFEKT: SUM N/5000
         [illegible]
         [illegible] CIA
         [illegible]
```

```
/        BEREGNING AF BORKONCENTRATION
/
HYDRA3.  CLA CLL CMA        /BEREGN KONCENTRATION I INDSPR.KAMMER
         DCA FTG            /FTG=-1
         TAD WP
         DCA HY31
         TAD CBO
         CIA
         DCA HY32
/        INDLAES BOR FLOW
         @ANIN:0
         SMA
         ISZ FTG            /FTG=0 FOR POS.BOR FLOW
         CIA
         MQL MUY
         @ED:137
         DVI
HY31.    0                  /WP
         CLA MQA
         SPA SZL
         JMP FEJL5
         ISZ FTG
         SKP
         CML CIA            /137*WBOR/WP
         TAD CBO+25         /+CBOR INLET
         CML
         TAD HY32           /-CBOR OUTLET
         SZL                /L=0:POS.
         CIA                /L=1:NEG.
         DCA HY32
         SNL
         CMA
         DCA FTG            /FTG=-1 FOR POS.AENDRING
         TAD VBO
         DCA .+5
         TAD WP
         MQL MUY
         @ED:69
         DVI
         0                  /VOLUMEN
         CLA MQA            /1024*DT*WP/(V*RO)
         TAD H1024
         DCA HY33
         MUY
HY32.    0                  /CB INLET-CB OUTLET+410*WBOR/WP
         DVI
HY33.    0                  /1024*(1+DT*WP/(V*RO))
         SZL
         JMP FEJL5
         TAD CBREST
         DCA CBREST
         TAD HY33
         CLL RAR
         CIA
         TAD CBREST
         STL
         SPA
         JMP .+7            /RESTSUM<DIVISOR/2.L=1
         CLA                /RESTSUM>DIVISOR/2.L=0
         TAD HY33
         CIA
         TAD CBREST         /NEDSAET RESTSUM MED DIVISOR
         DCA CBREST
         CLL
         CLA MQA
         SNL
```

```
        IAC             /FORHOEJ HVIS RESTSUM>DIVISOR/2
        CLL
        ISZ FTG
        CML CIA
        TAD CBO
        SZL
        JMP FEJ!6       /CBOR NEG
        DCA CBO
        JMP CBO1
/
FTG.    0
H1024.  2000
/
        ARRAY CBO BOR KONCENTRATION I SEKTIONERNE
        2*RORS ,2*DOWNC ,LOWER PL  4*CORES ,UPPER PL
        3*RORS ,OG INDK ,4*UROR,OG UDK ,2*RORS ,1*RORS
        CBO FINDES I DATABLOKKEN SIDST I PDP8 AFSNIT
/
        ARRAY CBREST REST ARRAY FOR BOR KONCENTRATION
        CBREST FINDES I DATABLOKKEN SAMMEN MED CBO
/
        ARRAY VBO VOLUMEN*200 I SEKTIONER FOR CBO
        DECIMAL
VBO.    235,235,442,442,1503,236,236,236,236,1067,235,235,235
        914,1045,1045,1045,1045,914,246,246,235
        OCTAL
/
        PAGE
/
CBO1.   TAD (CBO        /KONCENTRATION I 1 WP SEKTION
        DCA 20
        TAD (CBREST+1
        DCA 22
        TAD (VBO
        DCA 17
        CMA
        DCA 21
        TAD WP
        JMS CBOS
        TAD (-10        /KONCENTRATION I 8 WC SEKTIONER
        DCA 21
        TAD WC
        JMS CBOS
        TAD (-14        /KONCENTRATION I 12 WP SEKTIONER
        DCA 21
        TAD WP
        JMS CBOS
        TAD (CBO+5      /INDSAET BOR KONCENTRATION I A0-A15
        DCA 20
        TAD (A0+5
        DCA 27
        TAD (-4
        DCA 22
        TAD (-4
        DCA 21
        TAD I 20
        DCA I 27
        TAD 27
        TAD (10
        DCA 27
        ISZ 21
        JMP .-6
        ISZ 20
        ISZ 22
        JMP  -13
        JMP HYDRA4
```

```
/
CBOS.   0               /SUBROUTINE TIL KONCENTRATIONSBEREGN
        DCA W
        TAD I 17
        DCA  +5
        TAD W
        MQL MUY
        BED 69
        DVI
        0               /V
        CLA MQA
        TAD D1024
        DCA CBOSD
        TAD I 20        /CBOR INLET
        CML CIA
        ISZ 20
        TAD I 20        /CBOR OUTLET GAMMEL
        SZL             /L=0 FOR NEG AENDRING
        CIA
        DCA CBOSD-2
        SZL
        CMA
        DCA VV1         /VV1=-1 FOR POS AENDRING
        MUY
        0
        DVI
CBOSD.  0               /1024*(1+DT*W/(V+R0))
        TAD I 22
        DCA I 22
        TAD CBOSD
        CLL RAR
        CIA
        TAD I 22
        STL
        SPA
        JMP  +7         /RESTSUM<DIVISOR/2 L=1
        CLA             /RESTSUM>DIVISOR/2 L=0
        TAD CBOSD
        CIA
        TAD I 22        /NEDSAET RESTSUM MED DIVISOR
        DCA I 22
        CLL
        CLA MQA
        SHL
        IAC             /FORHOEJ HVIS RESTSUM>DIVISOR/2
        ISZ VV1
        CIA
        TAD I 20
        DCA I 20
        ISZ 22
        ISZ 21
        JMP CBOS+2      /NAESTE SEKTION
        JMP I CBOS      /FAERDIG
/
W.      0
WC.     0
WP.     0
VV1.    0
D1024.  2000
/
        PAGE
```

```
/       UDREGNING AF KONTROLSTANGSTAETHEDER (16 SEKTIONER)
/       -2040 SVARER TIL MAX  TAETHED
/
HYDRA4. CLA
        BANIN:7.HC5
        JMS CRPOS
        BFPPU:HYDRA5
/
CRPOS.  0
        TAD SEKTA       /NULSTIL CR TAETHED
        DCA HYD40
        TAD HYD40
        [illegible] IAC;CIA     /-(SEKTA+2)
        [illegible]
        TAD (A0+6
        [illegible]
        JMP [illegible]         /STANGPOS. NEG
        [illegible]
HYD40.  [illegible]
        [illegible]             /A0--2040
        [illegible]             /REST:-(0--3047)
        [illegible]
```

```
/       UDLAESNING AF FPP BEREGNINGER MED VIDERE
/       START FPP MED KINETIKBEREGNING
HYDRA5  BFPPST FPP1,360
/       INDSTIL DP2= 5789/(250*CPF)  DAMPGENERATOR
/          OG   DP3=.500/HFG
/          OG   DP4=10*ROGS/ROFS
HYD51   BDP:1,APD+4
        BDP:1,APD+5
        BDP:1,APD+6
/       INDSTIL DP5=(1-AT)* 0940;  TURBINE
/          OG   DP6=EG/1000
        BDP:1,TBD
        BDP:1,TBD+1
/       INDSTIL DP7=-(TPS-300)/100; PRESSURISER
        BDP:1,INX+4
/       INDSTIL DP8=SUMMA N/5000
        BDP:1,SUMN
/       INDSTIL DP9=CBOR/2000
        BDP 1,CBO
/       INDSTIL DP10=(VF-12)/20; PRESSURISER
/          OG   DP11=WE/50
/          OG   DP12=WC/50
/          OG   DP13=(TP2-250)/100
/          OG   DP14=(TUP-250)/100
        BDP:1,INX+1
        BDP:1,INX+2
        BDP:1,INX+3
        BDP:1,APD+3
        BDP:1,APD+7
/       UDLAES TP1 OG TP12 PAA AO6 OG 7. DAMPGENERATOR
        TAD APD+1;CIA;DCA APD+1
        BANOUT:6,APD+1
        BANOUT:7,APD+2
/       UDLAES TRI PAA AO4  TURBINE
        BANOUT:4,TBD+2
/       UDLAES DELTA P PRIMAER PAA AO0  PRESSURISER
        BANOUT:0,INX
/       INDSAET NY TCI
        CLA,TAD APD;DCA A0+2
        BFPPW
/       START FPP MED DELAYED NEUTRONBEREGN.
        BFPPST:FPP3,360
        CMA,DCA FPPSI   /INDIKATOR FOR HYDRA2 AFSNIT
        CMA;DCA ICINDI
        JMP HEAD
/
        PAGE
```

```
                SUBROUTINER
HIC,    0               /IC INDSTILLING
        @ANOUT 5,A0+2
        CLA
        DOC
/       IC SIGNAL
        @DO 5000
        JMS TRVENT
/       TS FORST 1 I STORE  IC SLUT
        @DO 2000
/       INDLAES RO INDLOB
        @ANIN 5
        CIA
        DCA A0+4
        @ANOUT 5,A0
        JMP I HIC
/
OPDA,   0               /OPDATER GL. VARIABLE OG INKREMENTER HDR.
        CLA
        TAD 11
        TAD (4
        DCA 11
        TAD SEKTA
        TAD ST
        SNA CLA
        JMP I OPDA      /1. GANG INGEN NYE VARIABLE
        TAD HJ0+1
        JMS DIVI;24
        TAD I 20        /TU
        DCA I 20
        ISZ 20
        TAD HJ0+2
        JMS DIVI;4
        TAD I 20        /TCA
        DCA I 20
        ISZ 20
        TAD HJ0+3
        JMS DIVI;5
        DCA OPDA1
        TAD OPDA1
        TAD WIC
        DCA WIC
        TAD OPDA1
        TAD I 20        /TC
        DCA I 20
        ISZ 20
        TAD HJ0+4
        JMS DIVI;5
        TAD I 20        /ALFA
        DCA I 20
        ISZ 20
        TAD HJ0+5
        CIA
        DCA I 20        /RO
        TAD 20
        TAD (4
        DCA 20
        TAD HJ0
        JMS DIVI;12
        TAD QK
        DCA QK          /SUMMA QK/500
        JMP I OPDA
OPDA1,  0
```

```
/
TRVENT, 0               /VENT PAA TRACK 2 SIGNAL SLUT
        DIC
        CLA CLL
        DIRC
        AND (2000
        SZA CLA
        JMP .-3
        JMP I TRVENT
/
/
FEJL0   @TYPE6:<NEG.WC>
FEJL1   @TYPE6:<NEG.WP>
FEJL4   @TYPE6:<STANGPOS.NEG.>
FEJL5   @TYPE6:<DIV OVERFL.BOR>
FEJL6   @TYPE6:<C-BOR NEG.>
FEJL7   @TYPE6:<FOR LANG REGNETID>
/
        PAGE
```



```
/       ICDATA UDLAESNING PAA FILE PWR.IC
/
ICUD,   FPRST
        RAR
        SZL CLA
        JMP .-3
        DCA FPPSI
        FPICL
        @ANIN 7,INDEKS
        TAD (FNPO
        JMS ENTER       /LUK FILE OP
/       START INDPAKNING AF FPP-TAL
        @FPPST:ICOUT,200
        @FPPW
        TAD (BUFFER     /UDLAES SIDSTE FPP BLOK
        JMS WRITE
        CLA
        TAD (ICLIH-1    /FLYT HELTAL
        DCA 10
        TAD (BUFFER-1
        DCA 11
        TAD (-401
        DCA 20
[illegible]     TAD I 10        /NAESTE LISTE ELEMENT
        [illegible]
        JMP ICUD3
        [illegible]
        DCA 21
        TAD I 10
        TAD (-1
        DCA 12
[illegible]     ISZ 20          /NAESTE ARRAY ELEMENT
[illegible]
        [illegible] TIL FILE PWR.IC>
        [illegible] ICOUT TIL UDLAESNING PAA DISK
[illegible]
```

```
/
/       LISTE MED ICDATA OG INPUT DATA PAA 12 BIT FORM
ICLIH,  1;SUMN
        20;N
        26;CBO
        26;CBREST
        10;APD
        10;TBD
        10;INX
        200;A0
        0
/
        PAGE
/
/       ICINDLAESNING FRA FILE PWR.IC
/
ICIND,  CLA
        TAD ICINDI
        SNA CLA
        JMP H1
        FPRST
        RAR
        SZL CLA
        JMP .-3
        DCA FPPSI
        FPICL
        TAD (FNPO
        JMS LOOKUP      /FIND FILE
        CLA
        TAD (BUFFER
        JMS READ
/       START UDPAKNING AF FPP-TAL
        @FPPST:ICIN,200
        @FPPW
        TAD (BUFFER
        JMS READ
        CLA
        TAD (ICLIH-1
        DCA 10
        TAD (BUFFER-1
        DCA 11
        TAD (-401
        DCA 20
ICIND1, TAD I 10        /NAESTE LISTE ELEMENT
        SNA
        JMP ICIND3
        CIA
        DCA 21
        TAD I 10
        TAD (-1
        DCA 12
ICIND2, ISZ 20
        JMP .+10
        TAD (BUFFER
        JMS READ
        CLA
        TAD (BUFFER-1
        DCA 11
        TAD (-401
        DCA 20
        CDF 10
        TAD I 11
        CDF 0
        DCA I 12
        ISZ 21
        JMP ICIND2
```

```
        JMP ICIND1
/
        PAGE
/
ICIND3  @ANOUT 8,INX
        @ANOUT 4,TBD+2
        @ANOUT 6,APD+1
        @ANOUT 7,APD+2
        CLA
        @DP 2,APD+4
        @DP I,APD+5
        @DP I,APD+6
        @DP I,TBD
        @DP I,TBD+1
        @DP I,INX+4
        @DP I,SUMN
        @DP I,CBO
        @DP I,INX+1
        @DP I,INX+2
        @DP I,INX+3
        CLA;DCA ICINDI
        @PRINT6 ICINDT
        DIC
        JMP H1
/
ICINDI, 0
ICINDT  @TEXT6 <ICDATA IND FRA FILE PWR.IC>
/
/       SUBROUTINE FOR ICIN TIL INDLAESNING FRA DISK
BUFIND, 0
        TAD (BUFFER
        JMS READ
        @FPPST:0,200
        JMP I BUFIND
/
        PAGE
/
/       STATISKE DATA IND FRA FILE PWR.ST
/
STAT,   FPRST
        RAR
        SZL CLA
        JMP .-3
        FPICL
        TAD (FNPOS
        JMS LOOKUP
        CLA
        TAD (BUFFER
        JMS READ
        @FPPST:STATF,200
        @FPPW
        JMS CRPOS           /FCR POSITION
        TAD (A0+15          /BOR KONCENTRATION
        DCA 20
        TAD (-17
        DCA 27
        TAD A0+5
        DCA I 20
        TAD (10
        TAD 20
        DCA 20
        ISZ 27
        JMP .-6
        TAD (CB0-1
        DCA 10
        TAD (-26
        DCA 27
        TAD A0+5
        DCA I 10
        ISZ 27
        JMP .-3
        DCA N+17
        TAD A15+2;CIA;DCA APD+1
        TAD A15+2;DCA APD+2
        TAD (3516;DCA APD+4
        TAD (2700;DCA APD+5
        TAD (2734;DCA APD+6
        TAD (6000;DCA TBD
        TAD (2000;DCA TBD+2
        TAD (3326;DCA INX+4
        @ANOUT:4,TBD+2
        @ANOUT:6,APD+1
        @ANOUT:7,APD+2
        CLA
        @DP:2,APD+4
        @DP:I,APD+5
        @DP:I,APD+6
        @DP:I,TBD
        @DP:7,INX+4
        @PRINT6:STATM
        JMP H1
/
        PAGE
/
STATM   @TEXT6:<STATISKE DATA FRA FILE PWR.ST>
FNPOS,  TEXT "PWR"
        0
        TEXT "ST"
/
LOG,    FPRST
        RAR
        SZL CLA
        JMP .-3
        DCA FPPSI
        FPICL
        @FPPST:FLOG,200
        @FPPW
        DIC
        JMP H1
/
        PAGE
```



```
N,      ZBLOCK 20           /NUCLEAR POWER,14 SEKTIONER+2
/
/       ARRAY CBO OG CBREST FOR BORKONCENTRATION
CBO,    ZBLOCK 26
CBREST, ZBLOCK 26
/
/       ARRAY APD:OVERFORSEL AF DATA FOR DAMPGEN. OG PRIM.KREDS
APD,    ZBLOCK 10
        N1C=APD+6
/
/       ARRAY TBD:OVERFORSEL AF DATA FOR TURBINE
TBD,    ZBLOCK 10
/
/       ARRAY INX:OVERFORSEL AF DATA FOR PRESSURISER
INX,    ZBLOCK 10
/
/       16 SEKTIONSARRAYS(8)
/       A0 OG A15 ER REFLEKTOR ARRAYS
/       ARRAY:TU,TCA,TC,ALFA,RO,CBOR,REG.STANG,INDEX
/
A0,     ZBLOCK 7;0
        ZBLOCK 7;1
        ZBLOCK 7;2
        ZBLOCK 7;3
        ZBLOCK 7;4
        ZBLOCK 7;5
        ZBLOCK 7;6
        ZBLOCK 7;7
        ZBLOCK 7;10
        ZBLOCK 7;11
        ZBLOCK 7;12
        ZBLOCK 7;13
        ZBLOCK 7;14
        ZBLOCK 7;15
        ZBLOCK 7;16
A15,    ZBLOCK 7;17
/
/       [illegible] INDEKS REG. CELLER
[illegible] ZBLOCK 10
[illegible]
```

```
/        FILE: PWR1.08
/       ROUTINE TIL KINETIK BEREGNING.
/
        ORG 10000
/       COMMON BASE PAGE
BASE0,  ZBLOCK 3*50
BUFFER, ZBLOCK 400
/
/       DATA TIL BEREGNING AF D,NY*SIGMA F-SIGMA A,NY*SIGMA F
KD,     F 1.2750E-6
        F -4.7000E-5
        F 6.4507
        F -4.7900E-1
        F 1.4000E-9
        F 1.1000E-5
        F 6.6E-3
        F 2.7665E-9
        F 4.5499E-6
        F 1.2033
KSFA,   F 3.05E-8
        F -6.69E-7
        F -8.76E-3
        F 8.05E-4
        F 2.236E-10
        F -2.0642E-6
        F -8.0E-4
        F 3.0219E-10
        F -6.0606E-7
        F 8.91E-4           /A0=2.55E-3 I SIGMA A
KSF,    F -1.4590E-1
        F 1.3522E-2
        F -1.9E-6
        F -6.4E-4
        F 2.6391E-2
KD0,    F 1.2750E-6
        F -4.7E-5
        F 6.4507
        F -4.7900E-1
        F 1.4E-9
        F 1.1E-5
        F 6.6E-3
        F 1.2033
KSA0,   F 6.929E-8
        F -1.405E-6
        F -1.3714E-1
        F 1.2717E-2
        F 7.0E-11
        F 3.402E-7
        F 2.4E-4
        F 2.4232E-2
/
        @REAL:<D,SA,NSF,FTU,FTC,FRO,FBO,FCR>
/
DX2,    F 679.645           /DELTAX**2
F3DX,   F 78.21             /3*DELTAX
DXR,    F .038358           / 1/DELTAX
BETA,   F 6.440E-3
F1,     F 1.
F2,     F 2.
F9,     F 9.
F16,    F 16
F2000,  F 2000.
NPTU,   F 65                /NULPUNKTFORSK   TU TVAERSNIT
NPTC,   F 2.                /        DO      TC    DO
NPRO,   F -.2296            /        DO      RO    DO
NPBO,   F -1500.            /        DO      BOR   DO
```

```
SFTU.    F - 24414        / -500/2048  SKALAFAKTOR TU IND
SFTC.    F  024414        / 50/2048      DO        TC
SFRO.    F  24414E-3      / 5/2048       DO        RO
SFBO.    F  48828         / 2000/4096    DO        BOR
SFCR.    F - 12207E-3     / - 25/2048    DO        REG STANG
PHIMIN.  F 1 E10
XX1.     F 0
XX2.     F 0
/
/
CCR.     F 0
         REPEAT 17
         F  375
CJI.     F 0
         REPEAT 17
         F 0
CJJ.     F 0
         REPEAT 17
         F 0
CJK.     F 0
         REPEAT 17
         F 0
PHI.     F 0
         REPEAT 17
         F 0
FNP.     F 0
         REPEAT 17
         F 0
NVSF.    F 0
         REPEAT 17
         F 0
SAZE.    F 0
         REPEAT 17
         F 0
SLCN.    F 0
         REPEAT 17
         F 0
CN1.     F 0
         REPEAT 17
         F 0
CN2.     F 0
         REPEAT 17
         F 0
CN3.     F 0
         REPEAT 17
         F 0
/
SFN.     F 1.7859E-10     / 2.10E-11*4096/500    SKALAFAKTOR N UD
F2040.   F 2040.
F4096.   F 4096.
/
/        KONSTANTER FOR FORSINKEDE NEUTRONER
LM1.     F 1.02           /LAMBDA1
LM2.     F .249
LM3.     F .0200
CN1K2.   F .833101        /(2-LM1*DT)/(2+LM1*DT)
CN1K1.   F 1.091309E-4    /(2*BETA1*DT)/(2-LM1*DT)
CN2K2.   F .975406
CN2K1.   F 3.906411E-4
CN3K2.   F .997124
CN3K1.   F 1.618330E-4
CN0K1.   F 0
```

```
/        BEREGN KOEFFICIENTER TIL DIFFUSIONSLIGNING
/
FPP1.    STARTF
         INDEX 0
         SETB KD           /SEKTION 1--14
         SETX A0+10; JSA KOEF
         SETX A0+20; JSA KOEF
         SETX A0+30; JSA KOEF
         SETX A0+40; JSA KOEF
         SETX A0+50; JSA KOEF
         SETX A0+60; JSA KOEF
         SETX A0+70; JSA KOEF
         SETX A0+100; JSA KOEF
         SETX A0+110; JSA KOEF
         SETX A0+120; JSA KOEF
         SETX A0+130; JSA KOEF
         SETX A0+140; JSA KOEF
         SETX A0+150; JSA KOEF
         SETX A0+160; JSA KOEF
/
         BASE KD0
         SETB KD0
         SETX A0           /SEKTION 0
         JSA KOEF0
         FLDA XX1
         FSTA CJK
         SETX A15          /SEKTION 15
         JSA KOEF0
         FLDA XX1
         FSTA CJI+55
         JA LOES
/////////
/        DEFINITION AF MAKRO TIL POLONOMIEBEREGNING
         @DEF @PARAM:X,KX,N
         @SET @A=N
         FLDA KX
         FMUL FTC
         FADD KX+3
         FMUL FTC
         FSTA X
         FLDA KX+6
         FMUL FRO
         FADD KX+11
         FMUL FRO
         FADDM X
         FLDA KX+14
         FMUL FBO
         FADD KX+17
         FMUL FBO
         FADDM X
         FLDA KX+22
         FMUL FCR
         @IFNE:@A,1^
         FADD KX+25
         FADDM X
         @IFEQ:@A,6^
         FLDA KX+25
         FMUL FTU
         FADD KX+30
         FMUL FTU
         FADD KX+33
         FADDM X
PARAM0
/////////
/        SUBROUTINE TIL KOEFFICIENT BEREGNING
         BASE KD
```



```
KOEF.    JA 0
/        OMSAET TU,TC,RO,BOR,CRPOS. TIL FLOATING FORM
         @FLOAT:0,SFTU,NPTU,FTU
         @FLOAT:2,SFTC,NPTC,FTC
         @FLOAT:4,SFRO,NPRO,FRO
         @FLOAT:5,SFBO
         JOE .+3; FADD' F2000
         FADD NPBO; FSTA FBO
         @FLOAT:6,SFCR(CCR,7)FCR
/        UDREGN D
         @PARAM:D,KD,1
/        UDREGN NY*SIGMAF-SIGMAA
         @PARAM:SA,KSFA,1
/        UDREGN NY*SIGMA F
         @CAL:KSF*FRO+(KSF+3)*FRO!NSF
         @CAL:((KSF+6)*FBO@NSF:(KSF+11)*FCR+(KSF+14)+NSF!NVSF,7>
         @CAL:(*BETA+SAZE,7-@SA>
/        BEREGN C(J,J-1),C(J,J),C(J,J+1)
         @CAL:(D/DX2!CJI,7!CJK,7*F2-+SA!CJJ,7>
         JA KOEF
/
/        SUBROUTINE TIL KOEF.BEREGNING I SEKTION 0 OG 15
         BASE KD0
KOEF0.   JA 0              /OMSAET FRA HELTAL
         @FLOAT:2,SFTC,NPTC,FTC
         @FLOAT:4,SFRO,NPRO,FRO
         @FLOAT:5,SFBO
         JOE .+3; FADD' F2000
         FADD NPBO; FSTA FBO
         @FLOAT:6,SFCR(CCR,7)FCR
/        UDREGN D
         @PARAM:D,KD0,0
/        UDREGN SIGMA A
         @PARAM:SA,KSAO,0
/        UDREGN D LED TIL CJ
         @CAL:[illegible]!XX2
         @CAL:[illegible]!XX1
         @CAL:[illegible]+SA-!CJJ,7>
         JA KOEF0
/
/        SLET MAKRO PARAM
         [illegible]
```

```
/        LØSNING AF DIFFUSIONSLIGNING
/
LOES.    BASE DX2
         SETB DX2
         SETX INDEKS
         LDX 0,7
         LDX -17,6          /SEKTIONSANTAL:16
LOL1.    FLDA CJI+3,7       /REDUCER MATRICEN
         FDIV CJJ,7
         FNEG
         FSTA XX1
         FMUL CJK,7
         FADDM CJJ+3,7
         FLDA XX1
         FMUL SLCN,7
         FADDM SLCN,7+
         JXN LOL1,6+        /RETUR HVIS FLERE SEKTIONER
         LDX 17,7           /SEKTIONSANTAL:16
         LDX -17,6
LOL2.    FLDA SLCN,7        /UDREGN PHI(N)
         FDIV CJJ,7
         FSTA PHI,7
         FMUL CJK-3,7
         FNEG
         FADDM SLCN-3,7
         FLDA PHI,7         /UDREGN FNP
         FSUB PHIMIN
         JOE .+3; FCLA
         FADD PHIMIN
         FMUL NVSF,7
         FSTA FNP,7
         ADDX -1,7
         JXN LOL2,6+        /RETUR HVIS FLERE SEKTIONER
         FLDA SLCN          /UDREGN PHI(N) FOR FØRSTE SEKTION
         FDIV CJJ
         FSTA PHI
/
/        OMSAET OG FLYT FNP SOM HELTAL
         BASE FNP
         SETB FNP
         SETX N+1
         LDX 0,7
         @DPFIX:0<FNP,7+>,SFN
         @DPFIX:1<FNP,7+>,SFN
         @DPFIX:2<FNP,7+>,SFN,OV0
         @DPFIX:3<FNP,7+>,SFN,OV0+2
         @DPFIX:4<FNP,7+>,SFN,OV0+4
         @DPFIX:5<FNP,7+>,SFN,OV0+6
         @DPFIX:6<FNP,7+>,SFN,OV0+10
         SETX N+10
         LDX 7,7
         @DPFIX:0<FNP,7+>,SFN,OV0+12
         @DPFIX:1<FNP,7+>,SFN,OV0+14
         @DPFIX:2<FNP,7+>,SFN,OV0+16
         @DPFIX:3<FNP,7+>,SFN
         @DPFIX:4<FNP,7+>,SFN
         @DPFIX:5<FNP,7+>,SFN
         @DPFIX:6<FNP,7+>,SFN
         FEXIT
/
OV0.     TRAP6 0            /OVERFLOW AF N/500
         TRAP6 1
         TRAP6 2
         TRAP6 3
         TRAP6 4
         TRAP6 5
```

```
TRAP6 6
TRAP6 7
```

```
/        BEREGNING AF KONCENTRATION AF FORSINKEDE NEUTRONER
/
         BASE LM1
FPP3,    STARTF
         SETB LM1
         SETX INDEKS
         LDX -16.6
         LDX 0.7
FPP3R,   FLDA FNP.7+         /GRUPPE 1
         FMUL CN1K1
         FADD CN1.7
         FMUL CN1K2
         FSTA CN1.7
         FMUL LM1
         FSTA CNX1
         FLDA FNP.7          /GRUPPE 2
         FMUL CN2K1
         FADD CN2.7
         FMUL CN2K2
         FSTA CN2.7
         FMUL LM2
         FADDM CNX1
         FLDA FNP.7          /GRUPPE 3
         FMUL CN3K1
         FADD CN3.7
         FMUL CN3K2
         FSTA CN3.7
         FMUL LM3
         FADD CNX1
         FNEG
         FSTA SLCN.7
         JXN FPP3R.6+
         FCLA
         FSTA SLCN
         FSTA SLCN+55
FPP3EX,  JA PROP
```



```
/        FILE  PWR2.08
/        BEREGNINGER FOR PRIMAER KREDS OG DAMPGENERATOR
/        ARRAY TPL:TCU,TUP,3*T-ROR,TP1,2*T-UROR,TPO,TP2,
/                2*T-ROR,3*T-ROR,2*TD,TLP
/        ARRAY VPL:SOM TPL DOG UDEN FORSTE ELEMENT
/        MED FK1 I STEDET FOR TPO POSITION
/        IND DATA:ARRAY APD:WC,WP,TCU,TPO,TSA,P,WIC
/        UD  DATA:ARRAY APD:T LOWER PL.,TP1,TP12,TP2,DP4,DP5,DP6,TUP
/
/
TPL,     F 310.
         REPEAT 7
         F 310.
         REPEAT 12
         F 300.
VPL,     F 46.6              /UPPER PLENUM
         F 1.177
         F 1.177
         F 1.177
         F 4.57              /DAMPGEN. INDLOB
         F 10.40
         F 10.40
FK1,     F 1                 /PLADS FOR TPO
         F 4.57
         F 1.33
         F 1.33
         F 1.173
         F 1.173
         F 1.173
         F 6.[illegible]              /REAKTOR DOWNCOMMER/2
         F 6.[illegible]
         F [illegible].75             /LOWER PLENUM
VC,      F [illegible].012            /VOLUMEN AF 1 CORE SEKTION
[illegible]  F [illegible]E-6         /CPP KONSTANTER
         F [illegible]72E-3
         F [illegible]
[illegible]  F [illegible]171[illegible]E-4   /HFG KONSTANTER
         F [illegible]E-2
         F [illegible]
[illegible]  F [illegible]E-4         /KONSTANTER TIL 10*ROGS/ROFS
         F [illegible]E-2
         F [illegible]E-6
[illegible]                  / 15000/2040 SKALAFAKTOR WC
[illegible]                  / 5000/2040       DO      WP
[illegible]                  /  25/2040        DO      P
[illegible]                  /  50/2040        DO      T
[illegible]                  / 4096*.5759/250  DO      APD4 UD
[illegible]                  / 4096*.500       DO      APD5
[illegible]                  / 4096            DO      APD6
[illegible]                  / 2040/50         DO      T
[illegible]
```

```
DRODTL,  F -1.60
DRODT,   F 0
/
         @REAL:(FWC,FWP,FTP,FTSA,FPR,WIN,XX5,XX6,XX7,XX8)
/
/
FPP2,    STARTF              /WC,WP,TCU,TPO,TSA,P OG WIC
         BASE TPL            /OMSAETTES TIL FPP FORM
         SETB TPL
         SETX APD
         @FLOAT:0,SFWC,,FWC
         @FLOAT:1,SFWP,,FWP
         @FLOAT:2,SFTIN,F300,TPL
         @FLOAT:3,SFTIN,F300,TPL+30
         @FLOAT:4,SFTIN,F250,FTSA
         @FLOAT:5,SFPR,F60,FPR
         @FLOAT:6,SFTIN
         @CAL:*DRODTM/FDT*VC-!WIN
/
/        TEMP.BEREGNING
/        TEMP.I UPPER PLENUM
         @CAL:FWC/FROK!XX7*FDT/VPL+FK1!XX8
         @CAL:-FK1*TPL+(TPL+3)/XX8!(TPL+3)
         @CAL:-TPL*XX7*DRODTH@WIN
         SETX INDEKS
         @CAL:FWP/FROK!XX8*FDT!XX6
         FLDA DRODTH,FSTA DRODT
         LDX -6.0
         LDX 1.7
         JSA FPP2S           /TEMP. TIL UDGANG AF U-ROR
         FLDA DRODTL,FSTA DRODT
         LDX -6.0
         LDX 10.7
         JSA FPP2S           /TEMP.TIL REAKTOR INDLOB
         @CAL:XX7!XX8*FDT!XX6
         LDX -3.0
         LDX 16.7
         JSA FPP2S           /TEMP.I REAKTOR FOR CORE
/        TP,MIDDEL TEMP.I U-ROR
         @CAL:(TPL+17)*F04!FTP:(TPL+20)*F06@FTP
/
/        UDREGN APD4=.5759/(250*CPP)
         SETX APD
         @POL:XX5,CPPK,2,FTP
         FLDA SFDP4
         FDIV XX5
         @DPFIX:4,,,,OV20+10
/        UDREGN APD5=.500/HFG
         @POL:XX5,HFUK,2,FTSA
         FLDA SFDP5
         FDIV XX5
         @DPFIX:5,,,,OV20+12
/        UDREGN APD6=10*(ROGS/ROFS)
         @POL:,ROFK,2,FPR
         @DPFIX:6,,,SFDP6,OV20+14
/        OMSAET T LOWER PLENUM TIL INDEX 0
         @FIX:0,TPL+63,F300,SFTUD,OV20
/        OMSAET TP1 TIL INDEX 1
         @FIX:1,TPL+17,F100,SFTUD,OV20+2
/        OMSAET TP12 TIL INDEX 2
         @FIX:2,TPL+25,F100,SFTUD,OV20+4
/        OMSAET TP2 TIL INDEX 3
         @FIX:3,TPL+33,F250,SFTUD
/        OMSAET T UPPER PLENUM TIL INDEX 7
         @FIX:7,TPL+3,F250,SFTUD
         JA TURB
```

```
/
/       SUBROUTINE  FL TEMP BEREGNING
FPP2S.  JA 0
        0CAL <XX6 VFL.7+FK1'XX5-FK1+TPL.7+(TPL+3.7)/XX5'(TPL.7+)>
        0CAL <-(TPL-3.7)+XX8*DRODT0WIN>
        JXN FPP2S+2.0+
        JA FPP2S
/
OV20.   TRAP6 20          /OVERFLOW T LOWER PLENUM
        TRAP6 21          /    DO     TP1 I DG
        TRAP6 22          /    DO     TP12 I DG
        TRAP6 23          /LEDIG
        TRAP6 24          /    DO      5759/250*CPF
        TRAP6 25          /    DO      580/HFG
        TRAP6 26          /    DO     10*ROGS/ROFS
```

```
/        TURBINEBEREGNINGER.
/       IND DATA  P-HIGH,P-LOW,Q-REHEATER
/       UD DATA: HP-TURBINE OUTLET X,E-GEN ,T-IN REHEATER
/       HELTALSDATA IND-UD OVER INDEKSREG. TBD
/
/
        0REAL:<PH,PL,TH,TL,QR,THGSP,THGS,THFS,SFS,SGS,EGEN>
        0REAL:<ENTH,ENTR,EG,KVA,DHR,DHH,TU1>
GMH.    F .8              /VIRKNINGSGRAD FOR HPT
GML.    F .8              /       DO          LPT
GMG.    F .95             /       DO          GEN.
KHX.    F 22.369          /KH*(1-AH)
SFSC.   F .4763           /SFS FOR KONDENSATOR
SFGSC.  F 7.9197          /(SGS-SFS)     DO
HFSC.   F 137.77          /HFS           DO
HFQSC.  F 2423.8          /(HGS-HFS)     DO
KHBH.   F 24.263          /KH*BETA FOR HPT
KLBL.   F 69.678          /KL*BETA FOR LPT
SPH.    F .048828         / 100/2048   SKALAFAKTOR FOR PH
SPL.    F .0097656        /  20/2048        DO          PL
SQR.    F 122.07          / 250*1000/2048   DO          QR
SKV.    F 3664.92         / 1.038*.862*4096 DO        (1-AT)
SEG.    F 4.096E-3        / 4096/1000/1000  DO          EG
STRI.   F 40.96           / 2048/50         DO          TRI
NTRI.   F 175.            / NULPUNKT FOR TRI
/
/       KONSTANTER TIL POLYNOMIER: HFS,HGS,SFS,SGS,TS LOW-HIGH
KHFS.   F .173105E-4
        F -.7054616E-2
        F 5.55901
        F -83.7610
KHGS.   F -.347027E-4
        F .141137E-1
        F -.041164
        F 2672.52
KSFS.   F .322284E-7
        F -.245531E-4
        F .153926E-1
        F -.236725E-1
KSGS.   F -.614785E-7
        F .460609E-4
        F -.185350E-1
        F 8.78514
KTH.    F -.156422E-4
        F .270145E-2
        F -.182786
        F 7.14733
        F 123.752
KTL.    F -.195021E-2
        F .955500E-1
        F -1.82370
        F 19.8697
        F 87.4263
/
/
        INDEX 0
        BASE PH
TURB.   SETX TBD
        SETB PH
        0FLOAT:0,SPH,,PH
        0FLOAT:1,SPL,,PL
        0FLOAT:2,SQR,,QR
        0POL:TH,KTH,4,PH
        0POL:TL,KTL,4,PL
        0POL:THGSP,KHGS,3,FTSA
        0POL:THFS,KHFS,3,TH
```



```
        0POL:THGS,KHGS,3,TH
        0POL:SFS,KSFS,3,TH
        0POL:SGS,KSGS,3,TH
/       KVA=X FOR HPT
        0CAL:THGS-THFS!TU1:THGSP-THFS/TU1!KVA
/       ENTR=S FOR HPT
        0CAL:SGS-SFS*KVA+SFS!ENTR
        0POL:THFS,KHFS,3,TL
        0POL:THGS,KHGS,3,TL
        0POL:SFS,KSFS,3,TL
        0POL:SGS,KSGS,3,TL
/       KVA=X EFTER HPT ISENTROPISK
        0CAL:SGS-SFS!TU1:ENTR-SFS/TU1!KVA
/       DHH=DELTA H FOR HPT MED TAB
/       ENTH=H EFTER HPT MED TAB
        0CAL:THFS-THGS*KVA-THFS+THGSP*GMH!DHH-+THGSP!ENTH
/       KVA=X EFTER HPT MED TAB
        0CAL:THGS-THFS!TU1:ENTH-THFS/TU1!KVA
        [illegible]FIX:0,,,SKV,OVF0
/       DHR=DELTA H FOR MELLEMOVERHEDER
/       ENTH=H EFTER         DO
        0CAL:[illegible]/KVR/PH!DHR+THGS!ENTH
/       KVA=X EFETR LPT ISENTROPISK
        0CAL:[illegible]-SFS/TU1[illegible]+SGS-SFSC/SFGSC!KVA
/       TU1=LPT EFFEKT
        0CAL:[illegible]*KVA*HFSC-+ENTH*GML*KLBL*PL!TU1
/       [illegible](HPT+LPT EFFEKT)*GEN. VIRKNINGSGRAD
        0CAL:[illegible]*PH+TU1*GMG!EGEN
        [illegible]:1,,,SEG,OVF0+2
        [illegible]:2,TL,NTRI,STRI,OVF0+4
        [illegible]
[illegible] [illegible] 30          /OVERFLOW (1-AT)*FAKTOR
        [illegible] 31          /    DO     GEN. EFFEKT
        [illegible] 32          /    DO     TRI I MELLEMOVERHEDER
```

```
/       PRESSURISER SIMULATOR.
/       INPUT WI FRA AFSNIT FPP2
/       OUTPUT VIA INX:P,VF,WE,PWC,TSA
/
DT.     F .1
VPR.    F 37.0
        POLYNOMIEKONSTANTER. NB:FAST RAEKKEFOLGE INDTIL HFSP
/
KPP.    F -1.82           / RFS
        F 875.
        F 1.04            / RGS: +6*1
        F -50.
        F -.92E-2         / DRFS/DP: +6*2
        F -.44
        F .0112           / DRGS/DP: +6*3
        F -.64
        F .40E-2          / HFS: +6*4
        F 1.011
        F -.29E-2         / HGS: +6*5
        F 3.049
        F -.010E-3        / DHGS/DP: +6*6
        F 1.60E-3
        F -730.           / DRF/DH: +6*7
        F 643.
        F .593E-2         / HWI: +6*10
        F -.4433
        F .504E-2          / HWK: +6*11
        F -.1762
        F .540            / TSA: +6*12
        F -30.9
HFSP.   F 4.E-3
RFP.    F 0.25
WIKO.   F .502E-3         / DT/(ROF*VOL. SURGE TUBE/3)
SP.     F 102.4           / 2048/20  SKALAFAKTOR P UD
SVF.    F 204.8           / 4096/20        DO      VF
SWE.    F 81.92           / 4096/50        DO      WE
SWC.    F 81.92           / 4096/50        DO      WC
STSA.   F 40.96           / 4096/100       DO      TSA
NVF.    F 12.
VF0.    F 22.
P0.     F 150.
/       REGULERINGSKONST. NB:FAST RAEKKEFOLGE
Q0.     F .030            /Q NULVAERDI
        F 1.              /Q DODBAAND
        F .16             /Q GAIN
        F 1.3             /Q MAX.
WK0.    F 0               /WK NULVAERDI. IC UDREGNING
        F 1.              /WK DODBAAND
        F 2.              /WK GAIN
        F 20.             /WK MAX.
WRD.    F 10.             /WR DODBAAND
        F 100.            /WR MAX.
F0.     F 0
F01.    F .1
F4.     F 4.
F5.     F 5.
F5000.  F 5000.
        0REAL:<HWK,HWI,HSU,=,=>
        0REAL:<P,PP,VF,VFP,VG,PWC,WE,WK,WI,WI0,WIP,WR,Q,PTSA>
        0REAL:<ROFS,ROGS,RFSP,RGSP,HFS,HGS,HFG,HGSP>
        0REAL:<HF,HFP,RFH,RF>
        0REAL:<X1,X2,FMI,FSHI>
```

```
         BASE DT
PRIC.    JA 0
         STARTF
         SETB DT
         @CAL Q0'Q P0'P VF0'VF
         @CAL VPR-VF'VG
         @POL HFS.6*4+KPF.1.P
         FSTA HF
         @POL HGS.6*5+KPF.1.P
         FSUB HFS.FSTA HFG
         @POL HWK.6*11+KPP.1.15*3+TPL
         @POL HWI.6*10+KPP.1.3*3+TPL
         @CAL 'HSU'(HSU+3)'(HSU+6)
         @CAL HGS-HWK-HFG'X1 Q0/X1'WK0'WK-!WI0!WI
         @CAL Q/HFG'WE
         @CAL WE+WK'PWC
         @CAL F0!PP'VFP'HFP'WR'FSHI
         @CAL F01'FMI
         JA PRIC
/
PROP.    STARTF
         SETX INX
         BASE DT
         SETB DT
/        PARAMETERBEREGNING
         @POL:ROFS.KPP.1.P
         @POL:ROGS.6+KPP.1.P
         @POL:RFSP.6*2+KPP.1.P
         @POL:RGSP.6*3+KPP.1.P
         @POL:HFS.6*4+KPP.1.P
         @POL:HGS.6*5+KPP.1.P
         @POL:HGSP.6*6+KPP.1.P
         @POL:RFH.6*7+KPP.1.HF
         @POL:HWI.6*10+KPP.1.3*3+TPL
         @POL:HWK.6*11+KPP.1.15*3+TPL
         @CAL:HF-HFS*RFH+ROFS!RF
         @CAL:HGS-HFS!HFG
/
/        FILTRERING AF WI
         @CAL:WI*F4+WIN+WI0/F5!WI
/
/        BEREGNING AF ENTALPI  I 3 SURGE TUBE KAMRE
         FLDA WI;JLT TWID;JEQ FM1
         @CAL:*WIKO!X1+F1!X2
         @CAL:HWI*X1+HSU/X2!HSU
         @CAL:*X1+(HSU+3)/X2!(HSU+3)
         @CAL:*X1+(HSU+6)/X2!(HSU+6)
         JA FM1
TWID     @CAL:-*WIKO!X1+F1!X2
         @CAL:HF*X1+(HSU+6)/X2!(HSU+6)
         @CAL:*X1+(HSU+3)/X2!(HSU+3)
         @CAL:*X1+HSU/X2!HSU
/
/        BEREGNING AF NY TILSTAND
FM1.     FLDA FMI;JEQ FUM1
/        VAND MAETTET
         @CAL:PP*RFSP*VF-+WI+PWC-WE/ROFS!VFP
         JA G1
/        VAND UMAETTET
FUM1     @CAL:HFP*RFH!X1:PP*RFP+X1*VF-+WI+PWC/RF!VFP
/        DAMP MAETTET
G1       @CAL:ROGS*VFP+WE+WK-PWC-WR/VG/RGSP!PP
/        WR.PWC.HF BEREGNING
FM2.     FLDA WI;JGT .+3;FCLA;FSTA WIP
         FLDA FMI;JEQ FUM2
/        VAND MAETTET
         @CAL:ROFS*HFSP-F01*PP*VF!X1
         @CAL:(HSU+6)-HFS*WIP+Q-X1/HFG+WE/F2
         JGE .+3;FCLA;FSTA WE;FSTA FMI
         JA G2
/        VAND UMAETTET
FUM2     @CAL:HF-(HSU+6)*WIP!X1:HFS-HF*PWC-X1!X1
         @CAL:PP*VF*F01+Q+X1/VF/RF!HFP
/        DAMP MAETTET
G2       @CAL:ROGS*HGSP-F01*PP*VG!X1
         @CAL:HGS-HWK*WK+X1/HFG
         JGE .+3;FCLA;FSTA PWC
         FLDA FSHI;JEQ .+6
         FCLA;FSTA' FSHI;JA FM1
         FLDA FMI;JNE FM3
         @CAL:HFP*DT+HF!HF
         FSUB HFS;JLT DPDV
         FLDA F01;FSTA FSHI
FM3      @CAL:HFS!HF!FMI
/        UDREGN DELTA P OG VF
DPDV     @CAL:PP*DT#P
         @CAL:VFP*DT#VF
         @CAL:VPR-VF!VG
/        BEREGN REGULERINGS INPUT VARIABLE
REG      @CAL:P0-P-(Q0+3)
         JGT .+3;FCLA
         @CAL:*(Q0+6)+Q0'Q
         FSUB Q0+11;JLE .+4;FLDA' Q0+11;FSTA' Q
         @CAL:P-P0-(WK0+3)
         JGT .+3;FCLA
         @CAL:*(WK0+6)+WK0!WK
         FSUB WK0+11;JLE .+4;FLDA' WK0+11;FSTA' WK
         @CAL:P-P0-WRD
         JGE .+5;FCLA;JA .+3;FLDA' WRD+3;FSTA WR
/        UDLAES VARIABLE
         @FIX:0.P.P0.SP.OVA40
         @DPFIX:1.VF.NVF.SVF.OVA40+2
         @DPFIX:2.WE..SWE.OVA40+4
         @DPFIX:3.PWC..SWC.OVA40+6
         @POL:PTSA.6*12+KPP.1.P
         @DPFIX:4...STSA.OVA40+10
         FEXIT
/
OVA40.   TRAP6 40        /OVERFLOW DELTA P PRIMAER
         TRAP6 41        /    DO    VAND VOLUMEN
         TRAP6 42        /    DO    WE
         TRAP6 43        /    DO    PWC
         TRAP6 44        /    DO    TSA PRIMAER
```



```
/        FILE  PWR3.08
/        FP-ICDATA UDLAESNING PAA FILE PWR.IC
/
         ORG 20000
         B0=BASE0
         BASE B0
         INDEX 0
ICOUT.   STARTF
         SETB B0
         SETX INDEKS
         @FLOAT:0.SFCRP..FCRP
         LDX -126.0
         LDX -1.1          /BUFFER INDEX:1
         FLDA ICBP         /KLARGOR BUFFER
         FSTA B0+11
         FLDA ICLP         /   DO   ADR-LIST
         FSTA B0
         LDX -1.7          /ICLIST INDEX:7
ICOUT1.  FLDAX B0.7+       /HENT EN ADR
         JEQ ICOUT3        /SLUTTEGN F 0
         FSTA B0+3
         LDX 14.6
         STARTD
         FLDA@ B0+3        /SET ANTAL SOM DOBBELT 12 BIT
         ALN 6
         FSTA@ B0+6
         LDX -1.5          /ARRAY INDEX:5
ICOUT2.  STARTF
         FLDAX B0+3.5+     /FLYT ET TAL
         JSA PUTICF
[illegible]
         [illegible] ICOUT2     /NAESTE TAL I ET ARRAY
[illegible]
         [illegible] ICOUT1     /NAESTE LISTE ELEMENT
ICOUT3.  [illegible]
/
[illegible]  [illegible] ICLIF
[illegible]  [illegible] BUFFER
[illegible]
[illegible]                / 1/2048
[illegible] TIL PAKNING I BUFFER OG TOMNING
[illegible]
[illegible] OF INPUT DATA PAA FPP FORM
[illegible]                /AFSKRIT FPP1
[illegible]
[illegible]                /AFSKRIT FPP2
[illegible]                /AFSKRIT FOP

         F 0
/
/        FPP ICDATA INDLAESNING FRA FILE PWR.IC
/
ICIN.    STARTF
         SETB B0
         SETX INDEKS
         LDX -126.0
         LDX -1.1
         FLDA ICBP
         FSTA B0+11
         FLDA ICLP
         FSTA B0
         LDX -1.7
ICIN1.   FLDAX B0.7+
         JEQ ICIN3
         FSTA B0+3
         LDX 14.6
         STARTD
         FLDA@ B0+3
         ALN 6
         FSTA@ B0+6
         LDX -1.5
ICIN2.   STARTF
         JSA GETICF
         FSTAX B0+3.5+
         STARTD
         FLDA@ B0+6
         FSUB@ DP1
         FSTA@ B0+6
         JGT ICIN2
         STARTF
         JA ICIN1
ICIN3.   JSA PRIC         /IC FOR PRESSURISER
         SETB B0
         @CAL:EGEN/F1000!TU1
         @FORM:F.F8.F4
         @TYPE8:<//REG.STANG POSITION=>
         @WRITE:F<FCRP>
         @FORM:F.F8.FPPONE
         @TYPE8:<//GENERATOR MW=>
         @WRITE:F<TU1./>
         FEXIT
/
/        SUBROUTINE TIL UDPAKNING FRA BUFFER
GETICF.  JA 0
         JXN .+10.0+
         TRAP3 BUFIND
         LDX -126.0
         LDX -1.1
         FLDAX B0+11.1+
         JA GETICF
```

```
/       STATISKE DATA IND FRA FILE FMS IT

STATF.  STARTF
        SETB 80
        SETX INDEKS
        LDX -1.7        FLYT PHI
        LDX  20.0
        FLDA BUFFER.7+
        FSTA PHI.7
        JXN  -4.0+

/       TRAP3 BUFIND    FLYT N
        LDX 0.7
        LDX -7.0
        LDX 13.1
        LDX -1.2
        LDX 0.6
        FCLA
        FSTA XX1
STATF1. FLDA BUFFER.7+
        FDIV FTI6
        FADDM XX1
        FLDA BUFFER.7
        FMUL F2048
        FDIV F500
        FDIV FTI6
        ALN 1
        STARTD
        ALN 2
        FSTA0 N-1.6+
        STARTF
        FLDA BUFFER.7+
        FDIV FTI6
        FADDM XX1
        FLDA BUFFER.7
        FMUL F2048
        FDIV F500
        FDIV FTI6
        ALN 1
        STARTD
        ALN 2
        FSTA0 N.6
        STARTF
        JXN STATF1.0+

/       TRAP3 BUFIND    /FLYT TU
        LDX 0.7
        LDX -16.0
        LDX 0.6
        FLDA BUFFER.7+
        FSUB F000
        FNEG
        FMUL F2048
        FDIV F500
        ALN 1
        STARTD
        FSTA0 A0+10.6
        STARTF
        ADDX 4.6
        JXN .-20.0+

/       TRAP3 BUFIND    /FLYT TCA
        LDX 0.7
        LDX -16.0
        LDX 0.6
        [illegible]

        FSUB F300
        FMUL F2048
        FDIV F100
        ALN 1
        STARTD
        FSTA0 A0+11.6
        STARTF
        ADDX 4.6
        JXN  -17.0+

/       TRAP3 BUFIND    /FLYT TC
        LDX -1.7
        LDX -20.0
        LDX 0.6
        FLDA BUFFER.7+
        FSUB F300
        FMUL F2048
        FDIV F50
        ALN 1
        STARTD
        FSTA0 A0+2.6
        STARTF
        ADDX 4.6
        JXN  -17.0+
        LDX -1.6        /INDSAET TEMP I TPL
        LDX -10.0
        FLDA BUFFER.7
        FSTA TPL.6+
        JXN .-4.0+
        LDX -12.0
        FLDA' BUFFER
        FSTA TPL.6+
        JXN .-3.0+

/       TRAP3 BUFIND    /FLYT ALFA
        LDX -1.7
        LDX -20.0
        LDX 0.6
        FLDA BUFFER.7+
        FMUL F2048
        FMUL F10
        ALN 1
        STARTD
        FSTA0 A0+3.6
        STARTF
        ADDX 4.6
        JXN .-15.0+

/       TRAP3 BUFIND    /FLYT ROF
        LDX -1.7
        LDX -20.0
        LDX 0.6
        FLDA BUFFER.7+
        FSUB F500
        FMUL F2048
        FDIV F500
        ALN 1
        STARTD
        FSTA0 A0+4.6
        STARTF
        ADDX 4.6
        JXN .-17.0+

/       TRAP3 BUFIND    /FLYT CN1
        LDX 0.7
        LDX -16.0
```



```
        FLDA BUFFER.7+
        FSTA CN1.7
        JXN .-4.0+

/       TRAP3 BUFIND    /FLYT CN2
        LDX 0.7
        LDX -16.0
        FLDA BUFFER.7+
        FSTA CN2.7
        JXN .-4.0+

/       TRAP3 BUFIND    /FLYT CN3
        LDX 0.7
        LDX -16.0
        FLDA BUFFER.7+
        FSTA CN3.7
        JXN .-4.0+

/       TRAP3 BUFIND    /FLYT SUM LAMBDA*CN
        LDX 0.7
        LDX -16.0
        FLDA BUFFER.7+
        FSTA SLCN.7
        JXN .-4.0+

/       TRAP3 BUFIND    /FLYT CCR
        LDX -1.7
        LDX -16.0
        FLDA BUFFER.7+
        FSTA CCR.7
        JXN .-4.0+

/       TRAP3 BUFIND    /FLYT XENON
        LDX -1.7
        LDX -16.0
        FLDA BUFFER.7+
        FSTA [illegible].7
        JXN .-4.0+

        TRAP3 BUFIND
        [illegible]     /FCR POSITION
        [illegible]
        [illegible]     /FCR VAEGT
        [illegible]
        [illegible]     /[illegible] KONCENTRATION
        [illegible]
        [illegible] STANG POSITION=>
        [illegible]
        [illegible] I [illegible]
        [illegible]

/
FTI6.   F 1 E6
FULL.   F 26 00         /FULL REACTOR POWER/100
```

```
/       LOGNING AF STATIONAERE VAERDIER
/
F14.    F 14
F3.     F 3.
F05.    F  5
NUF.    F 2 18E-11          /OMS FRA FNP TIL MW
KW.     F 25.95             /KW FOR TURBINE
HFGOR.  F 1570              /HFG I KW FOR REHEATER
/
        BASE B0
FLOG.   STARTF
        SETB B0
        SETX INDEKS
/       FLUX
        @TYPE8 </////FLUX />
        @FORM.P.F14.F3
        @WRITE P<PHI.,5*PHI+3,/,5*PHI+22,/,4*PHI+41,/,PHI+55,/>
/       NUKLEAR EFFEKT
        LDX -16.0,LDX -1,7
        FLDA FNP+3,7+
        FMULB NUF
        FSTA BUFFER,7
        JXN .-6,0+
        @TYPE8:</NUKLEAR EFFEKT I MW />
        @FORM.F.F8.F1
        JSA BUFOUT
/       URAN TEMP.
        LDX -16.0;LDX 0.1,LDX -1,2
URAN.   STARTD
        FLDA A0+10,1,FSTA0 INDEKS+4
        STARTF
        XTA 4
        FMUL SFTU;FADD F800
        FSTA BUFFER,2+
        ADDX 4,1
        JXN URAN,0+
        @TYPE8:</URAN TEMP. :/>
        JSA BUFOUT
/       KAPSEL TEMP.
        LDX -16.0;LDX 0.1;LDX -1,2
KAPSEL. STARTD
        FLDA A0+11,1;FSTA0 INDEKS+4
        STARTF
        XTA 4
        FMUL F100;FDIV F2048;FADD F300
        FSTA BUFFER,2+
        ADDX 4,1
        JXN KAPSEL,0+
        @TYPE8:</KAPSEL TEMP. :/>
        JSA BUFOUT
/       VAND TEMP.
        LDX -20.0;LDX 0.1;LDX -1,2
VAND.   STARTD
        FLDA A0+2,1;FSTA0 INDEKS+4
        STARTF
        XTA 4
        FMUL SFTC;FADD F300
        FSTA BUFFER,2+
        ADDX 4,1
        JXN VAND,0+
        @TYPE8:</VAND TEMP. :/>
        @WRITE:F<BUFFER,/,7*BUFFER+3,/,7*BUFFER+30,/,BUFFER+55,/>
/       TAETHED
        LDX -20.0;LDX 0.1;LDX -1,2
TAETH.  STARTD
        FLDA A0+4,1;FSTA0 INDEKS+4
        STARTF
        XTA 4
        FMUL SFRO;FADD F05
        FSTA BUFFER,2+
        ADDX 4,1
        JXN TAETH,0+
        @TYPE8:</VAND TAETHED:/>
        @FORM:F.F8.F4
        @WRITE:F<BUFFER,/,7*BUFFER+3,/,7*BUFFER+30,/,BUFFER+55,/>
/       ALFA
        LDX -16,0;LDX 0,1;LDX -1,2
ALFA.   STARTD
        FLDA A0+13,1;FSTA0 INDEKS+4
        STARTF
        XTA 4
        FMUL F5;FDIV F2048
        FSTA BUFFER,2+
        ADDX 4,1
        JXN ALFA,0+
        @TYPE8:</VOID I %:/>
        @FORM:F.F8.F2
        JSA BUFOUT
/       KONTROLSTAENGER
        @FORM:F.F8.F3
        @TYPE8:</FASTE KONTROLSTAENGER:/>
        @WRITE:F<CCR,/,7*CCR+3,/,7*CCR+30,/,CCR+55,/>
/       REAKTOR EFFEKT
        SETX SUMN
        XTA 0
        FMUL F5000;FDIV F4096
        JGE .+4;FADD0 F5000;FSTA BUFFER
        SETX INDEKS
        @TYPE8:</REAKTOR EFFEKT :>
        @FORM:F.F8.F1
        @WRITE:F<BUFFER>
/       REG.STANG
        SETX HC5
        XTA 0
        FDIV F2048
        FSTA BUFFER
        SETX INDEKS
        @TYPE8:</REG.STANG POS. :>
        @FORM:F.F8.F4
        @WRITE:F<BUFFER>
        @CAL:SFCR*F2048-!BUFFER
        @TYPE8:</REG.STANG VAEGT:>
        @WRITE:F<BUFFER>
/       BOR KONCENTRATION
        SETX A0
        XTA 5
        FMUL SF80;JGE .+4;FADD0 F2000
        FSTA BUFFER
        SETX INDEKS
        @TYPE8:</BOR KONCENTRATION I PPM:>
        @FORM:F.F8.F1
        @WRITE:F<BUFFER>
/       PRIMAER TRYK
        @TYPE8:</PRIMAER TRYK:>
        @FORM:F.F8.F2
        @WRITE:F<P>
/       PRIMAER MAETNINGSTEMP.
        @CAL:PTSA+F300!BUFFER
        @TYPE8:</PRIMAER MAETNINGSTEMP. :>
        @WRITE:F<BUFFER>
/       DAMPTRYK
        @TYPE8:</DAMPTRYK :>
```



```
        @WRITE.F<FPR>
/       DAMPTEMP.
        @TYPE8:</DAMPTEMP. :>
        @WRITE:F<FTSA>
/       STEAM LOAD
        @CAL:PH*KH!BUFFER:0R/HFGOR@BUFFER
        @TYPE8:</DAMP BELASTNING I KG PER SEK. :>
        @WRITE:F<BUFFER>
/       HP TURBINE TRYK
        @TYPE8:</HP TURBINE TRYK:>
        @WRITE:F<PH>
/       LP TURBINE TRYK
        @TYPE8:</LP TURBINE TRYK:>
        @WRITE:F<PL>
/       EL EFFEKT
        @CAL:EGEN/F1000!BUFFER
        @TYPE8:</EL EFFEKT I MW:>
        @WRITE:F<BUFFER,///>
        FEXIT
/
BUFOUT. JS 0
        @WRITE:F<7*BUFFER,/,7*BUFFER+25,/>
        JS BUFOUT
```

NO ERRORS
469 SYMBOLS, 221 LINKS

ADCC	06541	ADCY	06532	ADIC	06544	ADRB	06534
ADSC	06542	ADSF	06531	ALFA	22127	ANIN	04744
ANINSE	04754	AO0W	06302	AO1W	06312	AO2W	06322
AO3W	06332	AO4W	06342	AO5W	06352	AO6W	06362
AO7W	06372	APD	03674	APT	04437	APT0	04623
ASR	07415	A0	03724	A15	04114	BASE0	10000
BETA	11024	BIT2	00310	BUFFER	10170	BUFIND	03120
BUFOUT	23363	BUFUD	02512	B0	10000	CAM	07621
CBO	03620	CBOS	01245	CBOSD	01276	CB01	01200
CBREST	03646	CCR	11112	CJI	11172	CJJ	11252
CJK	11332	CLOSE	04235	CNX1	12256	CN1	11772
CN1K1	12237	CN1K2	12234	CN2	12052	CN2K1	12245
CN2K2	12242	CN3	12132	CN3K1	12253	CN3K2	12250
CPPK	13414	CRLF	24100	CRPOS	01407	D	10763
DHH	14221	DHR	14216	DIC	06504	DIR	06502
DIRC	06506	DISF	06501	DIVI	05000	DIVITG	05032
DOC	06111	DOW	06112	DPDA	06144	DPDV	16006
DPIA	06146	DPLA	06141	DPLX	06142	DP1	20073
DRODT	13562	DRODTH	13554	DRODTL	13557	DRODTM	13551
DT	14745	DYI	07407	DXR	11021	DX2	11013
D1024	01335	EG	14210	EGEN	14177	ENTER	04200
ENTH	14202	ENTR	14205	EXE1	04302	EXE4	04632
FBO	11005	FCON	24464	FCR	11010	FCSP	10100
FDT	13543	FEJL0	02210	FEJL1	02217	FEJL4	02226
FEJL5	02240	FEJL6	02253	FEJL7	02264	FINOUT	23411
FIO	00001	FK1	13353	FLOG	21310	FMI	15336
FM1	15617	FM2	15662	FM3	16003	FNP	11472
FNPO	02472	FNPOS	03417	FPEND	24061	FPLEND	25527
FPPOLD	24061	FPPONE	24061	FPPPI	24072	FPPPI2	24067
FPPSI	00677	FPPST	04400	FPPTWO	24064	FPPW	04447
FPP1	12261	FPP2	13623	FPP2PI	24075	FPP2S	14073
FPP3	13155	FPP3EX	13236	FPP3R	13166	FPR	13601
FPTRAP	04600	FRO	11002	FROK	13546	FR1	23525
FR4	23553	FSHI	15341	FTC	10777	FTG	01111
FT16	21260	FTP	13573	FTSA	13576	FTU	10774
FTYPE	24572	FULL	21263	FUM1	15635	FUM2	15720
FWC	13565	FWP	13570	FWRITE	23743	FWST	23567
FW0	23425	FW1	23462	FW3	23513	F0	15154
F01	15157	F04	13477	F05	21274	F06	13502
F1	11027	F10	13535	F100	13527	F1000	13524
F14	21266	F16	11040	F2	11032	F2000	11043
F2048	12215	F250	13510	F3	21271	F3DX	11016
F300	13513	F4	15162	F4096	12220	F5	15165
F50	13532	F500	13516	F5000	15170	F60	13505
F8	13540	F800	13521	F9	11035	GETADR	23647
GETC	23732	GETICF	20414	GETNUM	24116	GETSP	23710
GETTTY	04336	GLK	07204	GLORG	23411	GMG	14235

GMH	14227	GML	14232	G1	15651	G2	15741
HC4	01463	HC5	01464	HC6	01465	HEAC	00221
HF	15314	HFG	15306	HFGK	13425	HFGOR	21305
HFGSC	14254	HFP	15317	HFS	15300	HFSC	14251
HFSP	15055	HGS	15303	HGSP	15311	HIC	02000
HJ0	00540	HL	00416	HSU	15201	HW1	15176
HWK	15173	HYDRA1	00400	HYDRA2	00600	HYDRA3	01000
HYDRA4	01400	HYDRA5	01600	HYDR2	00637	HYD40	01477
HYD41	01457	HYD51	01604	HY31	01017	HY32	01052
HY33	01054	H1	00225	H1024	01112	ICBP	20070
ICI	00546	ICIN	20164	ICIND	02600	ICINDI	03101
ICINDT	03102	ICIND1	02636	ICIND2	02646	ICIND3	03000
ICIN1	20205	ICIN2	20223	ICIN3	20243	ICLIF	20120
ICLIH	02522	ICLP	20065	ICOUT	20000	ICOUT1	20026
ICOUT2	20044	ICOUT3	20064	ICUD	02400	ICUDT	02476
ICUD1	02432	ICUD2	02442	ICUD3	02462	INDEKS	04124
INSTP	00327	INS1	00324	INS2	00326	INX	03714
KAPSEL	21601	KD	10570	KD0	10703	KH	21302
KH0H	14257	KHFS	14312	KHGS	14326	KHX	14240
KLBL	14262	KOEF	12374	KOEF0	12546	KPP	14753
KSA0	10733	KSF	10664	KSFA	10626	KSFS	14342
KSGS	14356	KTH	14372	KTL	14411	KVA	14213
LM1	12223	LM2	12226	LM3	12231	LOES	12667
LOG	03423	LOL1	12677	LOL2	12724	LOOKUP	04246
LSR	07417	MCCPNS	25221	MCDIGC	24644	MCGETD	25017
MCLBLK	25127	MCPDOT	25211	MCPEXP	25145	MCPRTD	25233
MCPUTC	25060	MCRTP0	77000	MCRTP1	77030	MCRTP2	77033
MCRTP3	77036	MCRTP4	77041	MCRTP5	77044	MCRTP6	77047
MCRTP7	77052	MCRTP8	77055	MCSTAR	25111	MC1TAB	25251
MC2TAB	25307	MC260	25434	MC3TAB	25345	MC4TAB	25403
MQA	07501	MOL	07421	MUY	07405	N	03600
NMI	07411	NPBO	11057	NPRD	11054	NPTC	11051
NPTU	11046	NSF	10771	NTRI	14307	NUF	21277
NVF	15105	NYSF	11552	OPDA	02025	OPDA1	02107
OPM	00330	OVA40	16146	OVF0	14737	OV0	13135
OV20	14123	P	15212	PAGEAD	05000	PCON	24325
PGFAC	04354	PH	14141	PHI	11412	PHIMIN	11101
PL	14144	PP	15215	PRIC	15344	PRINT	04710
PROP	15445	PTSA	15261	PTYPE	24407	PUTC	23721
PUTICF	20103	PUTSTR	25464	PUTTTY	04322	PWC	15231
P0	15113	Q	15256	QK	00547	QR	14155
Q0	15116	READ	04262	REG	16017	RF	15325
RFN	15322	RFP	15060	RFSP	15272	RGFK	13436
RGSP	15275	RLF	04730	ROFS	15264	ROGS	15267
SA	10766	SAZE	11632	SCA	07441	SCL	07403
SEG	14301	SEKTA	00536	SFBO	11073	SFCR	11076
SFCRP	20075	SFDP4	13463	SFDP5	13466	SFDP6	13471
SFGSC	14246	SFN	12212	SFPR	13455	SFRO	11070
SFS	14171	SFSC	14243	SFTC	11065	SFTIN	13460
SFTU	11062	SFTUD	13474	SFWC	13447	SFWP	13452
SGS	14174	SHL	07413	SKV	14276	SLCN	11712
SLEND	05034	SLORG	04200	SP	15066	SPH	14265
SPL	14270	SQR	14273	ST	00537	STAT	03200
STATF	20431	STATF1	20467	STATN	03400	STL	07120
STR1	14304	STSA	15102	SUMN	00700	SVF	15071
SWC	15077	SWE	15074	TADR	04737	TAETH	22003
T00	03704	TEKST	04673	TEXE4	04664	TH	14147
TWFS	14166	TWGS	14163	TGHSP	14160	TL	14152
TOUT	04722	TPL	13240	TRVENT	02200	TTY1	00274
TURB	14430	TURSA	06136	TUSF	06131	TUSOR	06132
TU1	14224	TWID	15574	URAN	21516	USR	04277
VAN0	21670	V00	01113	VC	13411	VF	15220
VFP	15223	VF0	15110	VG	15226	VPL	13326
VPR	14750	W	01331	WC	01332	WE	15234
W1	15242	WIC	03702	WIKO	15063	WIN	13604
[illegible]	[illegible]	[illegible]	[illegible]	WK	[illegible]	WKO	[illegible]

WP	01333	WR	15253	WRD	15146	WRITE	04217
WRITEA	24005	WRITEB	24025	WRITER	23760	WRJA7	24051
XX1	11104	XX2	11107	XX5	13607	XX6	13612
XX7	13615	XX8	13620	X1	15330	X2	15333
YY1	01334						

APPENDIX B

Scaled equations, analog diagram, potentiameter list and DFG-tables for the core heat transfer model.

Scaled equations.

$$\left[\frac{\Delta_t T_u}{25}\right] = 1.0996\left(\left[\frac{N}{500}\right] - \left[\frac{Q_u}{500}\right]\right)$$

$$\left[\frac{\Delta_t T_{ca}}{25}\right] = 6.0478\left(\left[\frac{Q_u}{500}\right] - \left[\frac{Q_c}{500}\right]\right)$$

$$\left[\frac{\Delta T_u}{1000}\right]_{n+0.5} = 0.5\left[\frac{\Delta T_u}{500}\right]_n + 0.0125\left[\frac{\Delta_t T_u}{25}\right] \qquad (\Delta T_u = T_u - 1000)$$

$$\left[\frac{\Delta T_{ca}}{100}\right]_{n+0.5} = \left[\frac{\Delta T_{ca}}{100}\right]_n + 0.125\left[\frac{\Delta_t T_{ca}}{25}\right] \qquad (\Delta T_{ca} = T_{ca} - 300)$$

$$\left[\frac{T_\lambda}{1000}\right] = 0.5\left[\frac{\Delta T_u}{1000}\right]_{n+0.5} + 0.05\left[\frac{\Delta T_{ca}}{100}\right]_{n+0.5} + 0.1139\left[\frac{Q_u}{500}\right] + 0.65$$

$$\left[\frac{T_u - T_{ca}}{1500}\right] = 0.6667\left[\frac{\Delta T_u}{1000}\right]_{n+0.5} - 0.06667\left[\frac{\Delta T_{ca}}{100}\right]_{n+0.5} + 0.4667$$

$$\left[\tfrac{1}{3}Z_{ugca}\right] = 0.7750\left[\frac{2E-6}{\lambda_u}\right] + 0.1519$$

$$\left[\frac{Q_u}{500}\right] = \frac{1}{\left[\frac{1}{3}Z_{ugca}\right]}\left[\frac{T_u - T_{ca}}{1500}\right]$$

$$\left[\frac{T_{ca} - T_c}{100}\right] = \left[\frac{\Delta T_{ca}}{100}\right]_{n+0.5} - \left[\frac{\Delta T_c}{100}\right] - 0.5$$

$$\left[\frac{Q_{c1}}{500}\right] = 2.0584\left[\frac{W_c}{15000}\right]^{0.8}\left[\frac{T_{ca} - T_c}{100}\right]$$

$$\left[\frac{Q_{c2}}{500}\right] = 0.8785\left[\frac{T_{ca} - T_{ps}}{5}\right]^2$$

$$\left[\frac{\Delta T_c}{50}\right]^j_{n+1} = \left[\frac{\Delta T_c}{50}\right]^{j-1}_{n+1} + \frac{0.2}{\left[\frac{W_c}{15000}\right]}\left(0.3333\,\frac{\left[\frac{Q_c}{500}\right]^j}{\left[100C_p\right]} - 0.6747\left[\frac{\rho_f}{1000}\right]\left[\frac{\Delta_t T_c}{10}\right]^j_{n+1}\right)$$

(zeropoint: 300°C)

$$\left[\frac{\Delta_t T_c}{10}\right]^j_{n+1} = 5\left(\left[\frac{\Delta T_c}{50}\right]^j_{n+1} - \left[\frac{\Delta T_c}{50}\right]^j_n\right)$$

$$\left[\frac{\Delta T_c}{100}\right] = 0.25\left(\left[\frac{\Delta T_c}{50}\right]^{j-1}_{n+1} + \left[\frac{\Delta T_c}{50}\right]^{j}_{n+1} - 0.2\left[\frac{\Delta_t T_c}{10}\right]^{j}_{n+1} - 0.2\right)$$

(zeropoint: 250°C)

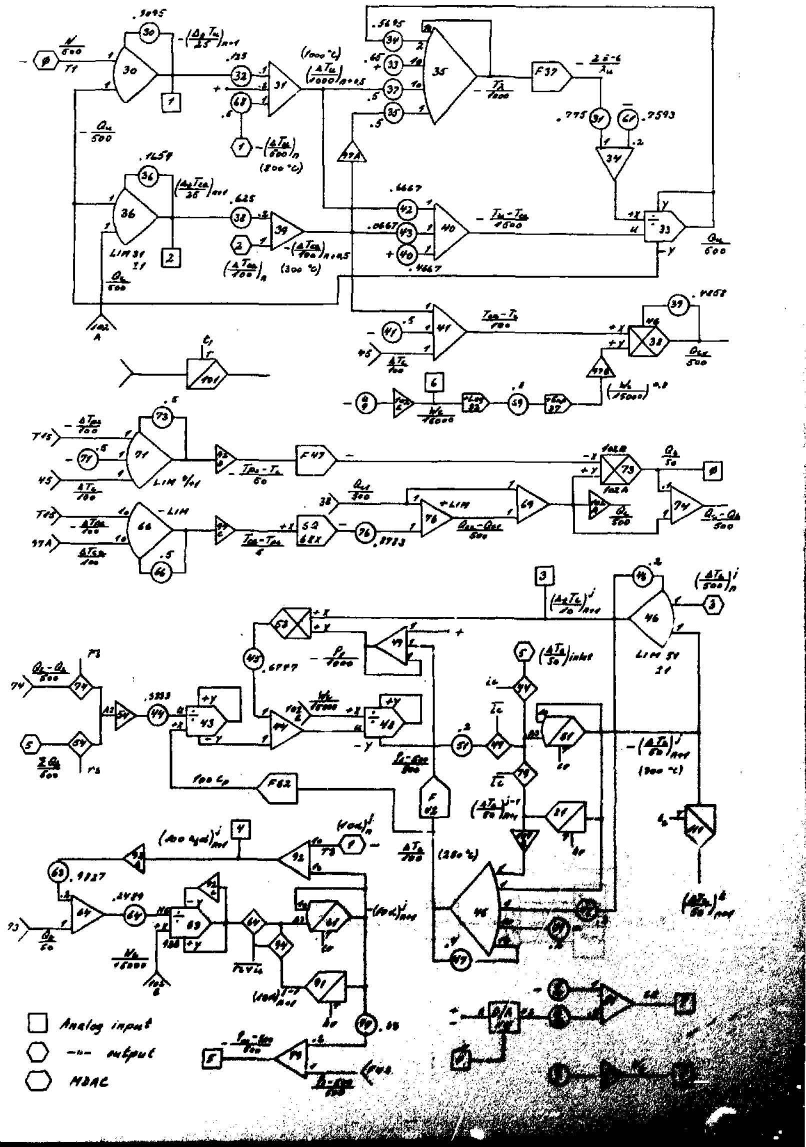
$$\left[\frac{Q_b}{50}\right] = \left[\frac{-Q_c}{500}\right] * F\left(\left[\frac{T_{ps}-T_c}{50}\right]\right)$$

$$[10\alpha]^{j}_{n+1} = [10\alpha]^{j-1}_{n+1} + \frac{0.2489}{\left[\frac{W_c}{15000}\right]}\left(\left[\frac{Q_b}{50}\right] - 0.1965\ [100\Delta_t\alpha]^{j}_{n+1}\right)$$

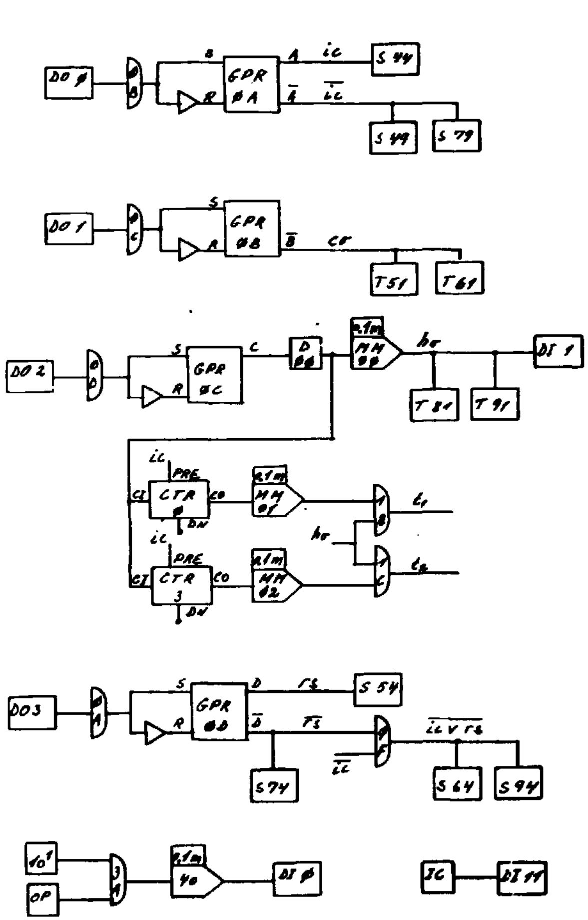
$$[100\Delta_t\alpha]^{j}_{n+1} = 10\left([10\alpha]^{j}_{n+1} - [10\alpha]^{j}_{n}\right)$$

$$\left[\frac{\rho_m-500}{500}\right] = \left[\frac{\rho_f-500}{500}\right] - 0.126\ [10\alpha]^{j}_{n+1}$$

Analog computing diagram for the core heat transfer.



Analog logic diagram.



Potentiometer list.

$$P30 = \frac{C_u}{\Delta t}\,\frac{SF\ N}{SF\ \Delta_t T_u} = \frac{1.819 \cdot 25}{0.1 \cdot 500} = 0.9095$$

$$P32 = \tfrac{1}{2}\,\frac{SF\ \Delta T_u}{SF\ \Delta_t T_u} \cdot 10 = \tfrac{1}{2} \cdot \frac{25}{1000} \cdot 10 = 0.125$$

$$P68 = 0.5$$

$$P36 = \frac{C_{ca}}{\Delta t}\,\frac{SF\ Q_u}{SF\ \Delta_t T_{ca}} = \frac{0.3307 \cdot 25}{0.1 \cdot 500} = 0.1654$$

$$P38 = \tfrac{1}{2}\,\frac{SF\ \Delta T_{ca}}{SF\ \Delta_t T_{ca}} \cdot 5 = \tfrac{1}{2} \cdot \frac{25}{100} \cdot 5 = 0.625$$

$$P33 = \tfrac{1}{2}\,(T_{uo} + T_{cao})\,(SF\ T_\lambda) = \tfrac{1}{2} \cdot \frac{1000 + 300}{1000} = 0.65$$

$$P37 = \tfrac{1}{2}\,\frac{SF\ T_\lambda}{SF\ T_u} = 0.5$$

$$P35 = \tfrac{1}{2}\,\frac{SF\ T_\lambda}{SF\ T_{ca}}\ 10 = 0.5$$

$$P34 = \tfrac{1}{2}\,Z_{gca}\,\frac{SF\ T_\lambda}{SF\ Q_u}\ 5 = \tfrac{1}{2} \cdot 0.4556 \cdot \frac{5}{2} = 0.5695$$

$$P61 = 5\ Z_{gca} \cdot (SF\ Z_{ugca}) = 5 \cdot 0.4556 \cdot \frac{1}{3} = 0.7593$$

$$P31 = K_u\,\frac{SF\ Z_{ugca}}{SF\ 1/\lambda_u} = \frac{4.65E\text{-}6}{3 \cdot 2E\text{-}6} = 0.775$$

$$P40 = (T_{uo} - T_{cao}) \cdot SF(T_u - T_{ca}) = \frac{1000 - 300}{1500} = 0.4667$$

$$P42 = \frac{SF\ (T_u - T_{ca})}{SF\ \Delta T_u} = \frac{1000}{1500} = 0.6667$$

$$P43 = \frac{SF\ (T_u - T_{ca})}{SF\ \Delta T_{ca}} = \frac{100}{1500} = 0.0667$$

$$P41 = (T_{cao} - T_{co}) \cdot SF\ T_c = \frac{300 - 250}{100} = 0.5$$

$$P39 = 1\Big/\left(\frac{0.023E\text{-}3}{D_{ec}^{\ 0.2}}\ O_{ca}\left(\frac{1}{A_c * SF\ W_c}\right)^{0.8} \cdot H_c\,\frac{SF\ Q_{cl}}{SF\ (T_{ca} - T_c)}\right)$$
$$= 1\Big/\left(\frac{0.023E\text{-}3}{0.01435^{0.2}}\ 280.9\left(\frac{15000}{3.88}\right)^{0.8}\ 0.92E\text{-}2 \cdot \frac{100}{500}\right) = 0.4866$$

$$P69 = 0.8$$

$$P73 = \frac{SF\ \Delta T_{ps}}{SF\ (T_{ps}-T_c)} = \frac{50}{100} = 0.5$$

$$P71 = (T_{pso} - T_{co}) * SF(T_{ps} - T_c) \cdot P73 = \frac{300-250}{50 \cdot 2}$$

$$P66 = \frac{SF\ \Delta T_{ps}}{SF\ (T_{ca} - T_{ps})} 10 = \frac{5}{100} \cdot 10 = 0.5$$

$$P76 = 1.373E-3 \cdot Q_{ca} \cdot \exp\left(\frac{P_p}{43.4}\right) \cdot \frac{5^2}{500} = 0.8782$$

$$P44 = \frac{SF\ W_c \cdot SF\ C_p}{SF\ Q} = \frac{500 \cdot 100}{15000} = 0.3333$$

$$P45 = \frac{V_c \cdot SF\ W_c}{\Delta t \cdot SF\ \rho_f \cdot SF\ \Delta_t T_c} = \frac{1.012 \cdot 1000 \cdot 10}{0.1 \cdot 15000} = 0.6747$$

$$P51 = 10 \cdot SF\ \Delta T_c = \frac{10}{50} = 0.2$$

$$P46 = \frac{SF\ \Delta T_c}{SF\ \Delta_t T_c} = \frac{10}{50} = 0.2$$

$$P47 = 2\frac{SF\ \Delta T_c}{SF\ T_c} \cdot \frac{1}{10} = 0.2 \cdot \frac{100}{50} = 0.4$$

$$P48 = \tfrac{1}{2} \frac{SF\ T_c}{SF\ \Delta_t T_c} \cdot 10 \cdot P47 = \tfrac{1}{2} \cdot \frac{10}{100} \cdot 4 = 0.2$$

$$P49 = (\Delta T_{co} - T_{co}) \cdot SF\ T_c \cdot P47 = (300-250) \cdot \frac{0.4}{100} = 0.2$$

$$P64 = \frac{\rho_f}{h_{fg}\ \rho_{gs}} \frac{SF\ W_c}{SF\ Q_k} 10 = \frac{725}{97.1} \cdot \frac{50 \cdot 10}{15000} = 0.2489$$

$$P63 = \frac{V_c}{\Delta t} h_{fg}\ \rho_{gs} \frac{SF\ Q_k}{SF\ \Delta_t \alpha} 5 = \frac{1.012}{0.1} \cdot 97.1 \cdot \frac{5}{50 \cdot 100} = 0.9827$$

$$P74 = (\rho_f - \rho_{gs}) \frac{SF\ \rho_m}{SF\ \alpha} 5 = 630 \cdot \frac{5}{500 \cdot 10} = 0.63$$

$$Q7 = W_b$$

$$Q9 = \frac{W_c}{15000} = 0.8460$$

Q12: ACR-position

Q14: CR-position

DFG-tables.

F32: $\lfloor 100\ C_p \rfloor$ MJ/kg °C at 150 bar.

T °C	$x = \frac{\Delta T_c}{100}$	C_p	$Y = \lceil 100 C_p \rceil$
250	0.00	0.00473	0.473
270	0.20	0.00495	0.495
290	0.40	0.00526	0.526
300	0.50	0.00548	0.548
310	0.60	0.00579	0.579
320	0.70	0.00621	0.621
330	0.80	0.00687	0.687
335	0.85	0.00737	0.737
340	0.90	0.00809	0.809
345	0.95	0.00905	0.905 } extension for 150 bar
305	1.00	0.01000	1.000 }

F42: $\lfloor (\rho_f - 500)/500 \rfloor$ kg/m³ at 150 bar

T °C	$\frac{\Delta T_c}{100}$	ρ_f kg/m³	$\frac{\rho_f - 500}{500}$ kg/m³
250	0.00	811.4	0.623
260	0.10	796.6	0.593
270	0.20	780.8	0.562
280	0.30	763.9	0.528
290	0.40	745.7	0.491
300	0.50	725.7	0.451
310	0.60	703.6	0.407
320	0.70	678.6	0.357
330	0.80	649.3	0.299
340	0.90	618.2	0.236
350	1.00	578.6	0.157

F37: $-\left[2E-6/\lambda_u\right]$ m °C/W

T °C	$\lambda = \frac{T}{1000}$	λ_u W/m °C	$\frac{2E-6}{\lambda_u}$
0	0.00	8.40	0.238
100	0.10	7.00	0.286
200	0.20	5.95	0.336
300	0.30	5.17	0.387
400	0.40	4.60	0.435
500	0.50	4.13	0.484
600	0.60	3.77	0.531
700	0.70	3.46	0.578
800	0.80	3.21	0.623
900	0.90	2.98	0.671
1000	1.00	2.78	0.719

F47: $\left[10 \cdot \frac{Q_b}{Q_c}\right]$

$\frac{T_{sa}-T_c}{50}$	$10\,\frac{Q_b}{Q_c}$
0.00	1.000
0.08	0.870
0.12	0.770
0.16	0.630
0.20	0.500
0.30	0.300
0.40	0.180
0.50	0.100
0.60	0.050
0.80	0.010
1.00	0.000

APPENDIX C

Scaled equations, analog diagram, potentiometer list, DFG-tables and parameter tables for the steam generator model.

Scaled equations.

$$\left[\frac{T_{po}}{50}\right] = \left[\frac{T_{pl,2}}{50}\right] - \left[\frac{\Delta T_{po}}{50}\right]$$

$$\left[\frac{\dot{\Delta T}_{po}}{50}\right] = 0.330\left(\frac{\left[\frac{Q_p}{1000}\right]}{\left[250\ C_{pp}\right]} - \left[\frac{W_p}{5000}\right]\left[\frac{\Delta T_{po}}{50}\right]\right)$$

$$\left[\frac{T_p}{50}\right] = 0.41\left[\frac{T_{pl}}{50}\right] + 0.59\left[\frac{T_{po}}{50}\right]$$

$$\left[\frac{\dot{T}_{r1}}{50}\right] = 4.036\left[\frac{Q_p}{2000}\right] - 5.017\left(\left[\frac{T_{r1}}{50}\right] - \left[\frac{T_{r2}}{50}\right]\right)$$

$$\left[\frac{\dot{T}_{r2}}{50}\right] = 5.017\left(\left[\frac{T_{r1}}{50}\right] - \left[\frac{T_{r2}}{50}\right]\right) - 2.018\left[\frac{Q_s}{1000}\right]$$

$$\left[\frac{Q_p}{2000}\right] = 0.8725\left[\frac{W_p}{5000}\right]^{0.8}\left[\frac{T_p - T_{r1}}{10}\right]$$

$$\left[\frac{Q_s}{1000}\right] = \left[\frac{T_{r2} - T_{ss}}{4.849}\right]^2$$

$$\left[\frac{Q_k}{1000}\right] = \left[\frac{Q_s}{1000}\right] - 0.260\left[\frac{W_s}{5000}\right]\left[\frac{T_{ss} - T_d}{10}\right]$$

$$\left[10\dot{U}\right] = \left[\frac{5.80}{h_{fg}}\right]\left[\frac{Q_k}{1000}\right] - 5.80\left[\frac{W_g}{1000}\right] - 1.14\left[\frac{\dot{p}_s}{2}\right]$$

$$\left[\frac{W_f}{5000}\right] = \left[\frac{W_s}{5000}\right] - 0.2\left[\frac{W_g}{1000}\right] + 0.756\left[10\dot{U}\right] + 0.0208\left[\frac{\dot{p}_s}{2}\right]$$

$$\left[\frac{W_g}{1000}\right] = 0.75\left[\frac{W_f}{5000}\right]\frac{[\alpha]}{[1-\alpha]}\left[10\,\frac{\rho_{gs}}{\rho_{fs}}\right]$$

$$[\alpha] = [U]\left(2.33 - 1.74\,[U]\right)$$

$$[\dot{\alpha}_r] = [\alpha] - [\alpha_r]$$

$$\left[\frac{\dot{p}_s}{2}\right] = 6.667\left(\left[\frac{W_g}{1000}\right] - \left[\frac{W_l}{1000}\right]\right) - 2.778\left[\dot{\alpha}_r\right]$$

$$\left[\frac{\dot{W}_b}{5000}\right] = \left[\frac{\dot{W}_f}{5000}\right] + 0.0112\left[\frac{\dot{P}_s}{2}\right] + 1.89\ [\dot{\alpha}_r]$$

$$\left[\frac{\dot{T}_b}{5}\right] = 0.0709\left[\frac{W_b}{5000}\right]\left[\frac{T_{sa}-T_b}{10}\right] - 0.1333\left[\frac{W_i}{1000}\right]\left[\frac{T_b-T_i}{100}\right]$$

$$\left[\frac{\dot{T}_d}{50}\right] = 0.1321\left[\frac{W_s}{5000}\right]\left[\frac{T_b-T_d}{10}\right]$$

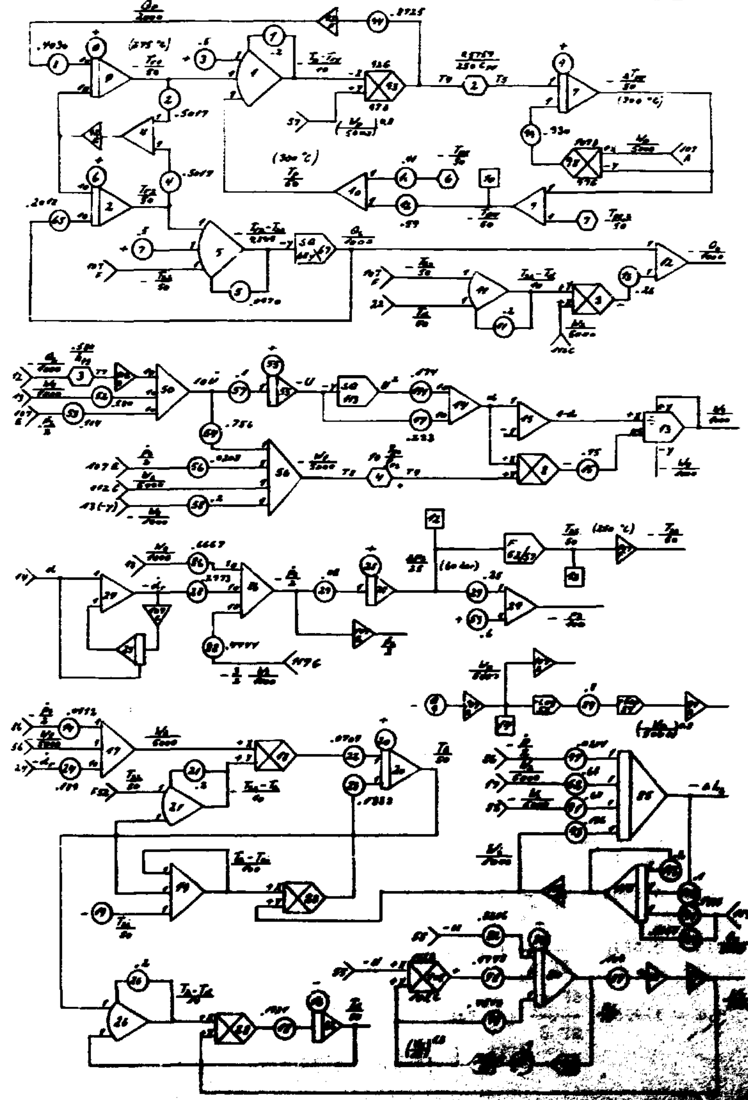
$$\left[\frac{\Delta p}{100\ \rho_{fs}}\right] = \left(0.5464 + 0.2152\ [U]\right)\left[\frac{v_d}{10}\right]^{1.8}$$

$$\left[\frac{\dot{v}_d}{10}\right] = 0.8206\ [U] - 0.826\left[\frac{\Delta p}{100\ \rho_{fs}}\right]$$

$$\left[\frac{W_s}{5000}\right] = 1.03\left[\frac{v_d}{10}\right]$$

$$[\dot{L}_t] = 0.680\left(\left[\frac{W_b}{5000}\right] - \left[\frac{W_s}{5000}\right]\right) + 0.136\left[\frac{W_i}{1000}\right] - 0.0204\left[\frac{\dot{P}s}{2}\right]$$

Analog computing diagram for the steam generator



Potentiometer list

$$P1 = \frac{SF\ T_{r1}}{SF\ (T_p - T_{r1})} = \frac{10}{50} = 0.2$$

$$P2 = \frac{1}{10} \cdot \frac{1}{C_r\ L_c} \frac{\lambda_r}{\Delta r} 2L_c O_r = 0.1 \cdot 0.1009 \cdot 49.71 = 0.5017$$

$$P3 = SF\ T_{r1} \cdot (\text{zerop. } T_p - \text{zerop. } T_{r1}) = \frac{300-275}{50} = 0.5$$

$$P4 = P2 = 0.5017$$

$$P5 = \frac{SF\ T_{r2}}{SF\ (T_{ss} - T_{r2})} = \frac{4.849}{50} = 0.0970$$

$$P7 = SF\ T_{r2} \cdot (\text{zerop. } T_{r2} - \text{zerop. } T_{ss}) = \frac{275-250}{50} = 0.5$$

$$P8 = \frac{1}{10} \cdot \frac{1}{C_r\ L_c} \frac{SF\ T_{r1}}{SF\ Q_p} = 0.1 \cdot 0.1009 \cdot \frac{2000}{50} = 0.4036$$

$$P65 = \frac{1}{10} \cdot \frac{1}{C_r\ L_c} \frac{SF\ T_{r2}}{SF\ Q_s} = 0.1 \cdot 0.1009 \cdot \frac{1000}{50} = 0.2018$$

$$P10 = a_p = 0.41$$

$$P12 = 1 - a_p = 0.59$$

$$P11 = \frac{SF\ T_d}{SF\ (T_{ss} - T_d)} = \frac{10}{50} = 0.2$$

$$P13 = c_{ps} \cdot \frac{SF\ Q_k}{SF\ W_s \cdot SF(T_{ss} - T_d)} = 0.0052 \cdot \frac{5000 \cdot 10}{1000} = 0.26$$

$$P94 = \frac{0.023E-3}{D_{ep}^{0.2}} O_p\ 2L_c \left(\frac{SF\ W_p}{A_p}\right)^{0.8} H_p \frac{SF\ Q_p}{SF\ (T_p - T_{r1})}$$

$$= 0.1917 \cdot 5000^{0.8} \cdot \frac{10}{2000} = 0.8725$$

$$P99 = \frac{1}{V_p\ \rho_f} \frac{1}{SF\ W_p} = 0.660E-4 \cdot 5000 = 0.330$$

$$P52 = 0.580E-3 \frac{1}{SF\ W_g} = 0.580E-3 \cdot 10 \cdot 1000 = 0.580$$

$$P53 = 0.0570 \cdot \frac{1}{SF\ \dot{p}_s} = 0.0570 \cdot 2 = 0.114$$

$$P54 = 37800 \cdot \frac{SF\ W_f}{SF\ \dot{U}} = 0.756$$

$$P56 = 52 \cdot \frac{SF\ W_f}{SF\ \dot{p}_s} = 0.0208$$

$$P57 = \frac{SF\ U}{SF\ \dot{U}} = 0.1$$

$$P58 = \frac{SF\ W_f}{SF\ W_g} = \frac{1000}{5000} = 0.2$$

$$P17 = 0.233$$

$$P111 = 0.174$$

$$P15 = \frac{1.5 \cdot SF\ W_g}{SF\ W_f \cdot SF(\rho_{gs}/\rho_{fs})} = \frac{1.5 \cdot 5000}{1000 \cdot 10} = 0.75$$

$$P27 = \frac{SF\ \Delta p_s}{SF\ \dot{p}_s} = \frac{2}{25} = 0.08$$

$$P28 = \frac{1}{10} \cdot \frac{V_r\ \rho_{gs}}{75} \frac{SF\ \dot{p}_s}{SF\ \dot{a}_r} = 0.1 \cdot \frac{416}{75} \cdot 0.5 = 0.2773$$

$$P29 = \frac{SF\ p_s}{SF\ \Delta p_s} = \frac{25}{100} = 0.25$$

$$P59 = SF\ p_s \cdot \text{zerop. } p_s = 0.01 \cdot 60 = 0.6$$

$$P86 = \frac{1}{10} \cdot \frac{1}{75} \frac{SF\ \dot{p}_s}{SF\ W_g} = \frac{1}{750} \cdot \frac{1000}{2} = 0.6667$$

$$P88 = \frac{1}{10} \cdot \frac{1}{75} \cdot \frac{SF\ \dot{p}_s}{SF\ W_1} = \frac{1}{750} \cdot \frac{2000}{3 \cdot 2} = 0.4444$$

$$P14 = C1 \frac{SF\ W_b}{SF\ \dot{p}_s} = 28 \frac{2}{5000} = 0.0112$$

$$P19 = \frac{250\ T_{si}}{SF\ T_{si}} = \frac{24}{50} = 0.48$$

$$P21 = \frac{SF\ T_{ss}}{SF\ (T_{ss} - T_b)} = \frac{10}{50} = 0.2$$

$$P22 = \frac{1}{V_{b1}\ \rho_{fs}} \frac{SF\ T_b}{SF\ W_b \cdot SF(T_{ss} - T_b)} = 0.709E-4 \cdot \frac{5000 \cdot 10}{50} = 0.0709$$

$$P23 = \frac{1}{V_{b1}\ \rho_{fs}} \frac{c_{pm}}{c_{ps}} \frac{SF\ T_b}{SF\ W_i \cdot SF(T_b - T_{si})} = 0.94 \cdot 0.709E-4 \cdot \frac{2000 \cdot 100}{50 \cdot 3} = 0.0889$$

$$P24 = \frac{V_r\ \rho_{fs}}{10} \frac{SF\ W_b}{SF\ \dot{a}_r} = 945 \cdot \frac{1}{5000} = 0.189$$

$$P18 = \frac{1}{V_d\ \rho_{fs}} \frac{SF\ T_d}{SF\ W_s \cdot SF(T_b - T_d)} = 1.921E-4 \cdot \frac{5000 \cdot 10}{50} = 0.1921$$

$$P26 = \frac{SF\ T_b}{SF(T_b - T_d)} = \frac{10}{50} = 0.2$$

$$P64 = 0.8$$

$$P61 = 0.9$$

$$P62 = \frac{g\ V_g/A_s}{\Sigma\ L_x A_d/A_x} \frac{SF\ v_d}{SF\ U} = 0.0826 \cdot 99.34 \cdot 0.1 = 0.8206$$

$$P7[illegible] = 0.2152 \cdot 0.826 = 0.1778$$

$$P7[illegible] = 0.5464 \cdot 0.826 = 0.4513$$

$$P87 = \frac{1}{10} \cdot A_d \rho_{fs} \frac{SF\ W_s}{SF\ v_d} = \frac{515}{10} \cdot \frac{10}{5000} = 0.103$$

$$P\ = \frac{1}{A_b\ \rho_{fs}} \frac{SF\ \Delta L_b}{SF\ W_b} = 0.136E-3 \cdot 5000 = 0.68$$

$$P\ = \frac{1}{A_b\ \rho_{fs}} \frac{SF\ \Delta L_b}{SF\ W_s} = 0.136E-3 \cdot 5000 = 0.68$$

$$P\ = \frac{1}{A_b\ \rho_{fs}} \frac{SF\ \Delta L_b}{SF\ W_i} = 0.136E-3 \cdot \frac{2000}{3} = 0.0907$$

$$P\ = \frac{\Sigma V}{A_b\ \rho_{fs}} \frac{d\rho_{fs}}{dp_s} \frac{SF\ \Delta L_b}{SF\ \dot{p}_s} = 0.136E-3 \cdot 75 \cdot 2 = 0.0204$$

IC-value potentiometers:

$P\emptyset$: $\frac{T_{r1}}{50}$, zeropoint: 275 °C

P[illegible]: $\frac{T_{r2}}{50}$, " : 275 °C

P[illegible]: $\frac{\Delta T_{po}}{50}$, " : 300 °C

P[illegible]: [illegible], " : 0

P2[illegible]: $\frac{T_b}{50}$, " : 250 °C

P1[illegible]: $\frac{T_d}{50}$, " : 250 °C

P25: $\frac{\Delta p_s}{75}$, " : 60 bar

P[illegible]: [illegible], " : [illegible]

DFG table

F 52/57: $(T_{ss}/50)$ °C

p bar	T °C	Δp bar	x	ΔT °C	y
35.0	242.5	-25.0	-1.000	-7.5	-0.150
37.5	246.5	-22.5	-0.900	-3.5	-0.070
40.0	250.3	-20.0	-0.800	0.3	0.006
42.5	254.0	-17.5	-0.700	4.0	0.080
45.0	257.4	-15.0	-0.600	7.4	0.148
47.5	260.7	-12.5	-0.500	10.7	0.214
50.0	263.9	-10.0	-0.400	13.9	0.278
52.5	267.0	-7.5	-0.300	17.0	0.340
55.0	269.9	-5.0	-0.200	19.9	0.398
57.5	272.8	-2.5	-0.100	22.8	0.456
60.0	275.6	0.0	0.000	25.6	0.512
62.5	278.2	2.5	0.100	28.2	0.564
65.0	280.8	5.0	0.200	30.8	0.616
67.5	283.3	7.5	0.300	33.3	0.666
70.0	285.8	10.0	0.400	35.8	0.716
72.5	288.2	12.5	0.500	38.2	0.764
75.0	290.5	15.0	0.600	40.5	0.810
77.5	292.8	17.5	0.700	43.8	0.856
80.0	295.0	20.0	0.800	45.0	0.900
82.5	297.2	22.5	0.900	47.2	0.944
85.0	299.2	25.0	1.000	49.2	0.984

Table C1

T	P	h_{fg}	ρ_{fs}	ρ_{gs}	$\frac{dh_{fs}}{dp_s}$	$\frac{dh_{gs}}{dp_s}$	$\frac{d\rho_{fs}}{dp_s}$	$\frac{d\rho_{gs}}{dp_s}$	$10\frac{\rho_{gs}}{\rho_{fs}}$	A	B	C
°C	bar	kJ/kg	kg/m³	kg/m³	$\frac{kJ/kg}{bar}$	$\frac{kJ/kg}{bar}$	$\frac{kg/m^3}{bar}$	$\frac{kg/m^3}{bar}$		$\frac{kJ/m^3}{bar}$	$\frac{kJ/m^3}{bar}$	$\frac{kJ/m^3}{bar}$
260	46.9	1660	784	23.7	6.5	-0.85	-2.05	0.54	0.303	876	5096	-20.1
270	55.1	1605	768	28.1	5.9	-1.10	-1.93	0.55	0.366	851	4531	-30.9
280	64.2	1540	751	33.2	5.4	-1.27	-1.82	0.57	0.442	836	4055	-42.2
290	74.5	1475	732	39.2	5.0	-1.41	-1.75	0.60	0.535	830	3660	-55.3
300	85.9	1400	712	46.2	4.6	-1.54	-1.70	0.63	0.649	811	3275	-71.1

$$A = \rho_{gs} \frac{dh_{gs}}{dp_s} + h_{fg} \frac{d\rho_{gs}}{dp_s}$$

$$B = \rho_{fs} \frac{dh_{fs}}{dp_s}$$

$$C = \rho_{gs} \frac{dh_{gs}}{dp_s}$$

Table C2

Load	P	V_g	α	U	F_α	D	E	C1	C2	$\Sigma R\Delta x$	W_g	τ_r
%	bar	m³				kg/bar	kg/bar	kg/bar	kg/bar	m	kg/s	sec.
115	49.2	25.6	0.739	0.490	1.45	91.2	-39.9	27.5	73.1	39.1	547	0.42
100	53.4	23.4	0.699	0.448	1.56	94.7	-43.3	27.9	73.8	34.4	475	0.50
90	56.4	21.7	0.673	0.416	1.62	97.2	-46.6	28.0	74.1	31.5	428	0.56
75	60.0	19.1	0.623	0.367	1.70	98.1	-51.2	27.4	73.8	27.5	356	0.68
65	63.3	17.45	0.583	0.335	1.73	98.0	-53.7	27.0	73.8	25.0	309	0.78
50	66.2	14.85	0.514	0.285	1.81	100.2	-58.2	27.6	74.9	21.7	237	0.98
40	71.4	12.70	0.461	0.243	1.90	102.8	-62.5	28.5	76	19.5	188	1.16
25	76.1	9.41	0.366	0.180	2.03	107.6	-68.8	30.5	78.4	16.5	119	1.55

$$D = \frac{1}{h_{fg}}(A\ V_g + B\ V_f - 100V_s)$$

$$E = V_g \frac{d\rho_{gs}}{dp_s} + V_f \frac{d\rho_{fs}}{dp_s}$$

$$C1 = \frac{1}{h_{fg}}(\rho_{fs} \frac{dh_{fs}}{dp_s} (V_{bo} + V_r(1-\alpha_r)) + (V_e+\alpha_r V_r)(\rho_{gs} \frac{dh_{gs}}{dp_s} - 100))$$

$$C2 = C1 + \frac{d\rho_{gs}}{dp_s} (V_e + \alpha_r V_r)$$

APPENDIX D

Scaled equations, analog diagram, potentiometer list, and DFG-table for the turbine-reheater model.

Scaled equations

$$\left[\frac{\dot{P}_h}{100}\right] = [illegible]\left[\frac{G_v}{2000}\right] - [illegible]\left[\frac{P_h}{100}\right]$$

$$\left[\frac{\dot{P}_l}{20}\right] = 4.4736\,(1-a_t)\left[\frac{P_h}{100}\right] - 2.94\left[\frac{P_l}{20}\right]$$

$$\left[\frac{G_v}{[illegible]}\right] = [illegible]\,[A_v]\left[\frac{P_v}{100}\right][Y_v]$$

$$\left[\frac{[illegible]}{[illegible]}\right] = 0.5346\,(1-a_t)\left[\frac{P_h}{100}\right]$$

$$\left[\frac{\dot{T}_{t1}}{50}\right] = 0.6818\left[\frac{T_{t1}-T_{t2}}{50}\right] - 0.1212\left[\frac{Q_r}{200}\right]$$

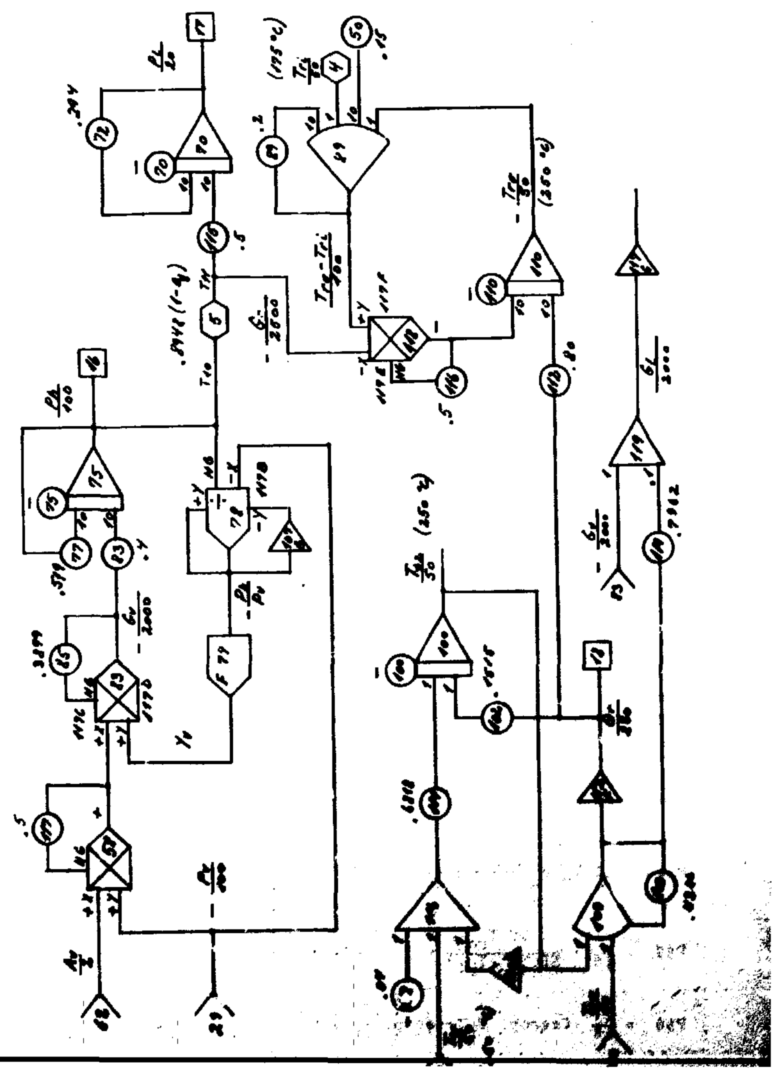
$$\left[\frac{T_{t1}-T_{t2}}{50}\right] = \left[\frac{T_{ss}}{50}\right] - \left[\frac{T_{t2}}{50}\right] - 0.04$$

$$\left[\frac{Q_r}{[illegible]}\right] = [illegible]\left[\frac{T_{t2}-T_{ro}}{50}\right]$$

$$\left[\frac{\dot{T}_{ro}}{[illegible]}\right] = [illegible]\left[\frac{Q_r}{200}\right] - 20\left[\frac{G_r}{2500}\right]\left[\frac{T_{ro}-T_{ri}}{100}\right]$$

$$\left[\frac{[illegible]}{[illegible]}\right] = \left[\frac{G_v}{[illegible]}\right] + 0.0637\left[\frac{Q_r}{200}\right]$$

Analog computing diagram for the turbine-reheater.



Potentiometer list

P117 = 0.5

$$P85 = \frac{1}{k_v}\,\frac{SF\ p_v}{SF\ G_v} = \frac{2000}{51.3\cdot 100} = 0.3899$$

$$P83 = \frac{1}{10}\cdot\frac{1}{V_h\,\frac{d\rho_g}{dp}}\,\frac{SF\ p_h}{SF\ G_v} = 0.1\cdot\frac{1}{10\cdot 0.5}\cdot\frac{2000}{100} = 0.4$$

$$P77 = \frac{1}{10}\cdot\frac{1}{V_h\,\frac{d\rho_g}{dp}}\,k_h = 0.1\cdot\frac{1}{10\cdot 0.5}\cdot 25.95 = 0.519$$

$$P72 = \frac{1}{10}\cdot\frac{1}{V_1\,\frac{d\rho_g}{dp}}\,k_1 = 0.1\cdot\frac{1}{50\cdot 0.5}\cdot 73.5 = 0.294$$

$$P115 = \frac{1}{10}\cdot\frac{1}{V_1\,\frac{d\rho_g}{dp}}\,\frac{SF\ p_1}{SF\ G_r} = 0.1\cdot\frac{1}{50\cdot 0.5}\cdot\frac{2500}{20} = 0.5$$

$$P118 = 2\cdot SF\ T_{t2} = 0.04$$

$$P114 = \frac{k_t}{C_t}\,\frac{SF\ T_{t2}}{SF(T_{t1}-T_{t2})} = \frac{22.5}{33} = 0.6818$$

$$P109 = \frac{1}{k_r}\,\frac{SF(T_{t2}-T_{ro})}{SF\ Q_r} = \frac{1}{11.4}\cdot\frac{250}{50} = 0.4386$$

$$P102 = \frac{1}{C_t}\,\frac{SF\ T_{t2}}{SF\ Q_r} = \frac{1}{33}\cdot\frac{250}{50} = 0.1515$$

$$P112 = \frac{1}{10}\cdot\frac{1}{V_1\,\rho_g\,C_p}\,\frac{SF\ T_{ro}}{SF\ Q_r} = 0.1\cdot\frac{1}{50\cdot 5\cdot 0.0025}\cdot\frac{250}{50} = 0.8$$

$$P116 = 10\,V_r\,\rho_g\,\frac{SF\ G_r\cdot SF(T_{ro}-T_{ri})}{SF\ T_{ro}} = 10\cdot 50\cdot 5\,\frac{50}{2500\cdot 100} = 0.5$$

$$P89 = \frac{1}{10}\cdot\frac{SF\ T_{ro}}{SF(T_{ro}-T_{ri})} = 0.1\cdot\frac{100}{50} = 0.2$$

$$P50 = \frac{1}{10}\cdot(\text{zerop. } T_{ro} - \text{zerop. } T_{ri})\cdot SF\ T_{ro} = 0.1\cdot(250-175)\cdot\frac{1}{50} = 0.15$$

$$P119 = \frac{10}{h_{fg}}\,\frac{SF\ G_1}{SF\ Q_r} = \frac{10}{1.57}\cdot\frac{250}{2000} = 0.7962$$

IC-value potentiometers:

P75 : p_h

P70 : p_1

P100: T_{t2} zeropoint: 250 °C

P110: T_{ro} - " - : 250 °C

DFG table

F77: $Y_v(p_h/p_v)$

$X = p_h/p_v$	Y
0.000	1.0000
0.575	1.0000
0.625	0.9943
0.675	0.9752
0.725	0.9414
0.775	0.8906
0.825	0.8191
0.875	0.7200
0.925	0.5787
0.950	0.4809
1.000	0.0000

APPENDIX E

Analog diagram and potentiometer list for the electrical power grid model.

Potentiometer list

$$P106 = \frac{1}{K_{el}} \frac{SF(E_g - E_{gr})}{SF\ A_v} = \frac{1}{0.004} \cdot \frac{2}{1000} = 0.5$$

$$P92 = \frac{1}{\tau\ S_r} \frac{SF\ \Delta f/f_n}{SF\ \Delta E/E_n} = \frac{1}{7.5 \cdot 2} \cdot \frac{50}{5} = 0.6667$$

$$P90 = \frac{1}{\tau} = \frac{1}{7.5} = 0.1333$$

$$P96 = \frac{100\ S_2}{10} \frac{1}{\tau_{2v}} \frac{SF\ \Delta E_2/E_2}{SF\ \Delta f/f_n} = \frac{100 \cdot 0.1 \cdot 5}{10 \cdot 0.25 \cdot 50} = 0.4$$

$$P67 = K_{e2} \frac{SF\ \Delta E_2/E_2}{SF\ \Delta f/f_n} = 1 \cdot \frac{5}{50} = 0.1$$

$$P98 = \frac{1}{10 \cdot \tau_{2v}} = \frac{1}{10 \cdot 0.25} = 0.4$$

P95 = P98 = 0.4

$$P107 = \frac{1}{10 \cdot \tau_{2t}} = \frac{1}{10 \cdot 0.5} = 0.2$$

$$P109 = \frac{E_2}{E_n} = \frac{4130}{5000} = 0.826$$

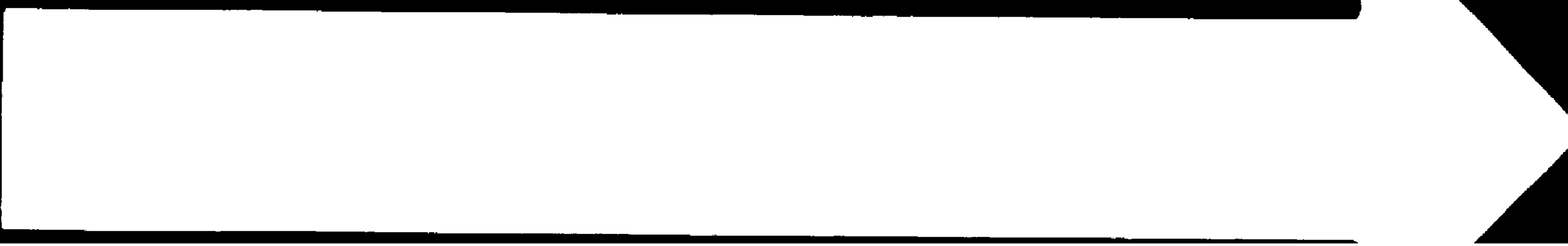
$$P104 = \frac{1}{E_n} \frac{SF\ \Delta E/E_n}{SF\ \Delta E_g} = \frac{1}{5000} \cdot 5 \cdot 1000 = 1$$

P80: U-value for $A_v/2$

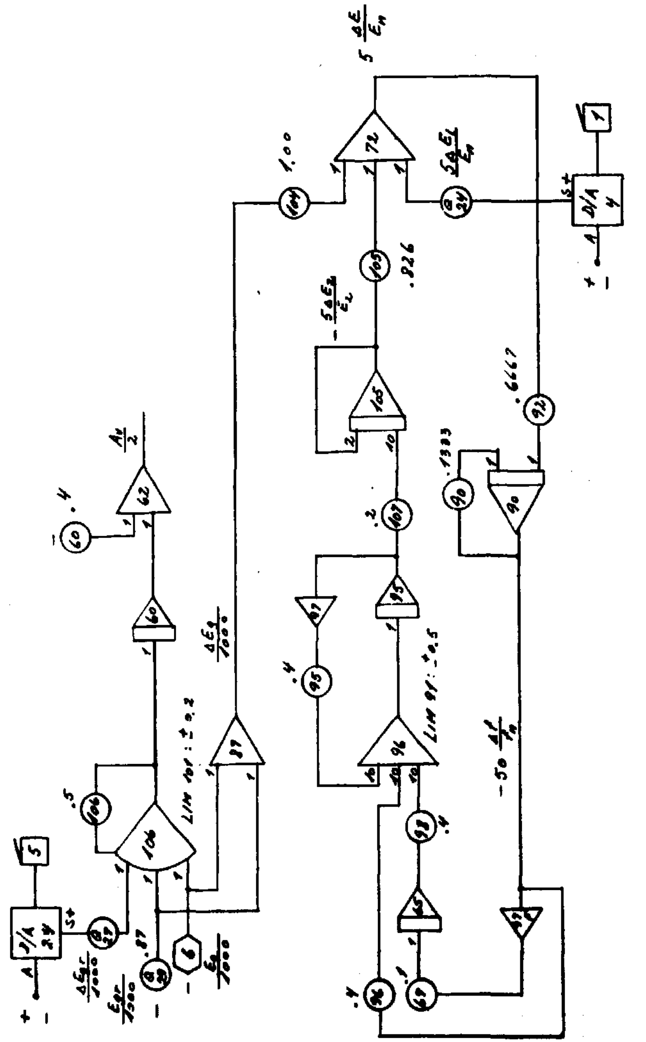
Q24: 5 $\Delta E_1/E_n$

Q29: $E_{gr}/1000$

Q27: $\Delta E_{gr}/1000$



Analog computing diagram for the power grid.



APPENDIX F

Interface connections:

MDAC	0:	$\frac{N}{500}$	Reactor
-"-	1:	$(10\,\alpha)^j_n$	-"-
-"-	2:	$\frac{0.5759}{250\, c_{pp}}$	Steam generator
-"-	3:	$\frac{0.580}{h_{fg}}$	- " -
-"-	4:	$10\,\frac{\rho_{gs}}{\rho_{fs}}$	- " -
-"-	5:	$0.8948(1-a_t)$	Turbine
-"-	6:	$\frac{E_g}{1000}$	-"-
-"-	7:	$-\frac{\Delta T_{ps}}{100}$	Pressurizer
-"-	8:	$\frac{\Sigma N}{5000}$	Reactor
-"-	9:	$\frac{C_{bor}}{2000}$	-"-
-"-	10:	$\frac{V_f-12}{20}$	Pressurizer
-"-	11:	$\frac{W_e}{50}$	-"-
-"-	12:	$\frac{W_e}{50}$	-"-
-"-	13:	$\frac{T_{p2}}{50}$	Steam generator
AO	0:	$\frac{\Delta p_p}{20}$	Pressurizer
-"-	1:	$-(\frac{\Delta T_u}{500})^j_n$	Reactor
-"-	2:	$(\frac{\Delta T_{ca}}{100})^j_n$	-"-

AO 3:	$(\frac{\Delta T_c}{50})^j_n$	Reactor
-"- 4:	$\frac{T_{ri}}{50}$	Turbine
-"- 5:	$(\frac{\Sigma Q_k}{500})^j_n$ or $\frac{\Delta T_{ca}}{50}$	Reactor
-"- 6:	$-\frac{T_{pl}}{50}$	Steam generator
-"- 7:	$\frac{T_{pl2}}{50}$	- " -
AI 0:	$(\frac{Q_k}{50})^j_n$	Reactor
-"- 1:	$-(\frac{\Delta_t T_u}{25})^j_{n+1}$	-"-
-"- 2:	$(\frac{\Delta_t T_{ca}}{25})^j_{n+1}$	-"-
-"- 3:	$(\frac{\Delta_t T_c}{10})^j_{n+1}$	-"-
-"- 4:	$(100\ \Delta_t \alpha)^j_{n+1}$	-"-
-"- 5:	$-\frac{\rho_m - 500}{500}$	-"-
-"- 6:	$\frac{W_i}{15000}$	-"-
-"- 7:	CR-position	-"-
-"- 8:	W_b	Primary loop
-"- 9:	Not used	
-"- 10:	$-\frac{T_{po}}{50}$	Steam generator
-"- 11:	Not used	
-"- 12:	$\frac{\Delta P_s}{25}$	Steam generator

AI 13:	$\frac{T_{ss}}{50}$	Steam generator
-"- 14:	$\frac{W_p}{5000}$	- " -
-"- 15:	Not used	
-"- 16:	$\frac{P_h}{100}$	Turbine
-"- 17:	$\frac{P_l}{20}$	-"-
-"- 18:	$\frac{Q_r}{250}$	-"-

Error messages:

System errors: FFP DIV. Ø
FPP EXP. OVERFLOW

Both messages are self-explanatory. No exit address is given, but it may be found by ODT in APT(9-11) plus (APT+1). The octal address for APT is given in the address list in appendix A.

FILE ERR.

FILE END

occurs only in connection with reading from disk files, an IC file or a static data file. The first means that the file is not present on the disc, the other means that the file is too short.

Program errors:

NEG.WC	:	W_c goes negative
NEG.WP	:	W_p goes negative
STANG POS. NEG.	:	Regulating rod position goes negative
DIV.OVERFL.BOR	:	Overflow by division during calculation of boron acid concentration
C-BOR NEG.	:	Boron acid concentration goes negative
FOR LANG REGNETID	:	The calculation for one time step takes more than 0.1 sec., possibly due to a long "track" time in the core hybrid computations (MM Ø)

TRAP6 messages:

0-7:	Overflow by conversion of nuclear power to integers for core sections 3-10. Section power > 500 MW.		MDAC 0
20	Overflow T-lower plenum	$\lvert T-300\rvert > 50\ ^{o}C$	
21	- " - T_{pl}	- " -	A0 6
22	- " - T_{pl2}	- " -	A0 7
24	- " - $0.5759/(250\ c_{pp})$		MDAC 2
25	- " - $0.580/h_{fg}$		MDAC 3
26	- " - $10\ \rho_{gs}/\rho_{fs}$		MDAC 4
30	- " - $0.8948\ (1-a_t)$		MDAC 5
31	- " - $E_g/1000$		MDAC 6
32	- " - T_{ri}	$\lvert T-175\rvert > 50\ ^{o}C$	A0 4
40	- " - p_p	$\lvert p-150\rvert > 20$ bar	A0 0
41	- " - V_f	$\lvert V_f-22\rvert > 10\ m^3$	MDAC 10
42	- " - $W_e/50$		MDAC 11
43	- " - $W_c/50$		MDAC 12
44	- " - T_{ps}	$\lvert T-350\rvert > 50\ ^{o}C$	MDAC 7

Limiter settings:

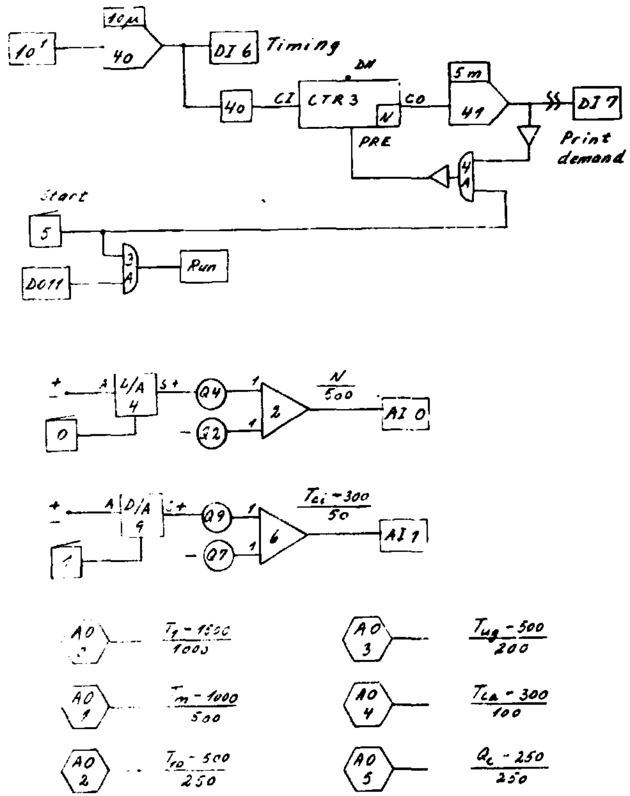
LIM 31 = ±1	saturation limiter for $\Delta_t T_{ca}$
" 51 = ±1	- " - - " - -"-
" 71 = 0, +1 exact	$0 \leq (T_{ps}-T_c)/50 \leq 1$
" 91 = ±0.5	$(SF\ \Delta E_2/E_2)/T_{v2} = 5/10$
" 101 = ±0.2	$(SF\ A_v/2)/T_{v1} = 0.5/2.5$

MM pulse length:

MM 00 = 100 μs
MM 01 = 100 "
MM 02 = 100 "
MM 40 = 100 "

APPENDIX G

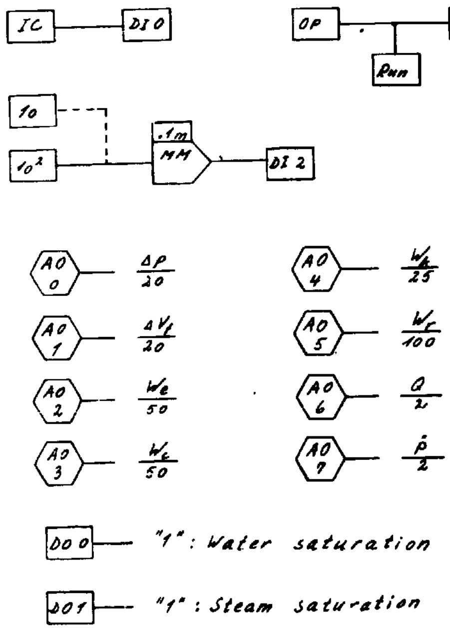
Program listing and analog connections for the ten-shell section fuel model.




```
C           FILE. P1.FT
C           BRAENDSELSMODEL.    MARTS 73.
C           10 SEKTIONER. GE-MODEL MED RADIUS DELING
C           N IND VIA AI(0). NULP.:0. GAIN:500
C           TC IND VIA AI(1). NULP.:300. GAIN:50
C           T(1). T(MIDDEL). T(10). TUG. TCA. QC UD PAA:
C           AO(0). AO(1). AO(2). AO(3). AO(4). AO(5)
C           NULP. : 1500. 1000. 500. 500. 300. 250
C           GAIN  : 1000. 500. 250. 200. 100. 250
C           TIMINGSIGNAL DI(6)
C           PROFILUDSKRIFT SIGNAL DI(7)
C
C
            REAL M(11). K(11). C(11). D(11). T(11). O(6)
            REAL A(11,3)
            REAL LA.LCA.KG.M
C
C
            DATA RU.DRG.DRCA.N/.4655,.002,.062,32920/
            DATA X.DEC.AC/26.07,.01435,3.08/
            DATA LCA.KG.RGU.CUS.ROCA.CCAS/ 15.4 ,10.0,.32,6.5,.31/
            DATA PI/3.14159/
            DATA NC.DT/12690.,.1/
            DATA T.TUG/12*300./
C
C
            [illegible]
            [illegible]+DRCA
            [illegible]+.5*DRCA
            [illegible]1./(KG*X*M)+DRCA/(2*PI*RCA*X*M*LCA))*1.E6
            [illegible]
            [illegible]((2*J+1.)/(2*J-1.))
            [illegible](20./19.)
            [illegible]1.E-4
            [illegible](NC/AC)**.8/(DEC**.2)
            [illegible]CUS*1.E-6
            [illegible]
            [illegible]-1)/(100*DT)
            [illegible]**2)*X*M*ROCA*CCAS*1.E-6)/DT
            [illegible]
            [illegible]
            [illegible]
            [illegible]
            [illegible]
            [illegible]
            [illegible]
            [illegible](TF+300))
            [illegible](J)*T(J)
            [illegible]T(11)
            [illegible]
            [illegible]**3)*1.E-6
            [illegible]
            [illegible]**3)*1.E-6
            [illegible]
            [illegible]
            A(J,2)=K(J-1)+K(J)+C(J)
40          A(J,3)=-K(J)
C
C           LOES LIGNINGSSYSTEMET
            DO 45 J=1,10
            F=-A(J+1,1)/A(J,2)
            A(J+1,2)=A(J+1,2)+F*A(J,3)
45          D(J+1)=D(J+1)+F*D(J)
            T(11)=D(11)/A(11,2)
            DO 50 J=1,10
            F=-A(11-J,3)/A(12-J,2)
            D(11-J)=D(11-J)+F*D(12-J)
50          T(11-J)=D(11-J)/A(11-J,2)
            TUG=(T(10)-T(11))*ZGCA*K(10)+T(11)
C
C           UDREGN OUTPUT VARIABLE OG UDLAES
            TM=T(8)+.429*(T(7)-T(8))
            QC=K(11)*(T(11)-TC)
            O(1)=(T(1)-1500)/1000
            O(2)=(TM-1000)/500
            O(3)=(T(10)-500)/250
            O(4)=(TUG-500)/200
            O(5)=(T(11)-300)/100
            O(6)=(QC-250)/250
            DO 55 J=1,6
55          CALL ANI(2,J-1,O(J),0,0)
C
C           PROFILOUTPUT ?
            CALL ANI(6,0,1,7,L)
            IF (L) 20,20
            CALL ANI(5,0,0,11,0)
            WRITE(4,100) (T(J),J=1,10),TM,TUG,T(11),QC
            CALL ANI(5,0,1,11,0)
            GO TO 20
100         FORMAT(1H0,10F7.1,/,1H ,2/3F7.1,3X,F7.1)
            END
```

APPENDIX H

Program listing and analog connections for the detailed pressuriser model.



```
        ORG 10000
INDEKS. ZBLOCK 10
BASEB.  ZBLOCK 3*50
        /DATACELLER
DT.     F .1
V.      F 37.0
HWK.    F 1.230
HWI.    F 1.450
NADR.   F 10.
NADR.   F 4.
KRFS.   F -4.79920E-3
        F -0.426907
        F 775.435
KRGS.   F 5.03223E-3
        F -0.684103
        F 67.9683
KRFSP.  F -2.82339E-6
        F 1.06206E-3
        F -0.135616
        F 4.1627
KRGSP.  F 1.94994E-6
        F -7.23306E-4
        F 9.55994E-2
        F -3.63699
KHFS.   F 2.36941E-6
        F 3.34697E-3
        F 1.055577
KHGS.   F -1.55610E-5
        F 1.72963E-3
        F 2.708997
KHFSP.  F 2.52025E-7
        F -7.1493E-5
        F 9.6007E-3
KHGSP.  F -3.76720E-9
        F 1.42010E-6
        F -0.202406E-3
        F 8.11117E-3
KRFH.   F -1.55856E3
        F 4.16825E3
        F -3.2043983
KRGH.   F 0.61E3
        F -1.74E3
KRGP.   F -0.7
        F 2.49
RFP.    F 0.25
CPG.    F .018          / CP FOR DAMP NAER MAETNING
DTSP.   F .6            / DT/DP FOR MAETTET DAMP
KGGV.   F .2            / VARMEOVERGANGSTAL DAMP-VAEG
CV.     F 10.           / VARMEKAPACITET VAEG
SP.     F 102.4         / 2048/20  SKALAFAKTOR P UD
SVF.    F 204.8         / 2048/10       DO    VF
SWE.    F 40.96         / 2048/50       DO    WE
SWC.    F 40.96         / 2048/50       DO    WC
SWK.    F 81.92         / 2048/25       DO    WK
SWP.    F 20.48         / 2048/100      DO    WR
SQ.     F 1024.         / 2048/2        DO    Q
SPP.    F 1024.         / 2048/2        DO    PP
        GREAL:<F1=1.,F2=2.,F01=.1,F0=0.F4096=4096.>
        GREAL:<VFG.PG.G0.GD.GK.GN.WKD.WKK.WKN.WRD.WRN.WKG.WIG>
        GREAL:<P.PP.VF.VFP.VG.WC.WE.WK.WI.WIP.WR.Q>
        GREAL:<ROFS.ROGS.RFSP.RGSP.HFS.HGS.HFG.HFSP.HGSP>
        GREAL:<HF.HG.HFP.HGP.RFH.RGP.RGH.RF.RG>
        GREAL:<X1.FMI.GMI.LI>
        GREAL:<DWI.DWIT.TT.WIST.WIRP.DDWI>
        GREAL:<PPG.VFPG.WEG.WCG.HFPG.HGPG>
        GREAL:<DTV.DTGV.GGV.TVP>

G1.     0.1
```

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```
        B-BASED
        BASE B
        INDEX B
PST.    STARTF
        SETX INDEKS
        SETB B
        [illegible]:F.NADR.NADR
        [illegible]:<//VFG.PG.GG: >
        [illegible]:<VFG.PG.GG>
        [illegible]:F<VFG.PG.GG./>
        [illegible]:</G: OFFSET.GAIN.MAX. : >
        [illegible]:<GD.GK.GN>
        [illegible]:F<GD.GK.GN./>
        [illegible]:</WK: OFFSET.GAIN.MAX: >
        [illegible]:<WKD.WKK.WKN>
        [illegible]:F<WKD.WKK.WKN./>
        [illegible]:</WR: OFFSET.FLOW: >
        [illegible]:<WRD.WRN>
        [illegible]:F<WRD.WRN./>
        [illegible]
        [illegible]:[illegible]!WK:PG!P:VFG!VF
        [illegible]
        [illegible]!WRP!WR!DTV!WIRP
        [illegible]
        [illegible]DELTA T OG STEPSWITCH: >
        [illegible]

FOP.    STARTF
        SETX INX
        BASE DT
        SETB DT
        /PARAMETERBEREGNING
        BPOL:ROFS.KRFS.2.P
        BPOL:ROGS.KRGS.2.P
        BPOL:RFSP.KRFSP.3.P
        BPOL:RGSP.KRGSP.3.P
        BPOL:HFS.KHFS.2.P
        BPOL:HGS.KHGS.2.P
        BPOL:HFSP.KHFSP.2.P
        BPOL:HGSP.KHGSP.3.P
        BPOL:RFH.KRFH.2.HF
        BPOL:RGH.KRGH.1.HG
        BPOL:RGP.KRGP.1.HG
        BCAL:HF-HFS*RFH+ROFS!RF
        BCAL:HG-HGS*RGH+ROGS!RG
        BCAL:HGS-HFS!HFG
        BCAL:HG-HGS/CPG!X1:P-P0*DTSP-DTV+X1!DTGV
        BCAL:*KGGV!GGV/CV!TVP
        /
        /BEREGNING AF NY TILSTAND
FM1.    STARTF
        FLDA FMI;JEQ FUM1
        /VAND MAETTET
        BCAL:PP*RFSP*VF-+WI+WC-WE/ROFS!VFP
        JA G1
FUM1.   /VAND UMAETTET
        BCAL:HFP*RFH!X1:PP*RFP+X1*VF-+WI+WC/RF!VFP
G1.     FLDA GMI;JEQ GUM1
        /DAMP MAETTET
        BCAL:ROGS*VFP+WE+WK-WC-WR/VG/RGSP!PP
        JA FM2
GUM1.   /DAMP UMAETTET
        BCAL:VG*HGP*RGH!X1
        BCAL:RG*VFP+WE+WK-WR-X1/VG/RGP!PP
        /WE.WC.HF.HG BEREGNING
FM2.    FLDA WI;JGT .+3;FCLA;FSTA WIP
        FLDA FMI;JEQ FUM2
FM2A.   /VAND MAETTET
        BCAL:ROFS*HFSP-F01*PP*VF!X1
        BCAL:HWI-HFS*WIP+Q-X1/HFG+WE/F2
        JGE .+3;FCLA;FSTA WE;FSTA FMI
        JA G2
FUM2.   /VAND UMAETTET
        BCAL:HF-HWI*WIP!X1:HFS-HF*WC-X1!X1
        BCAL:PP*VF*F01+Q+X1/VF/RF!HFP
G2.     FLDA GMI;JEQ GUM2
        /DAMP MAETTET
        BCAL:ROGS*HGSP-F01*PP*VG!X1
        BCAL:HGS-HWK*WK+X1+GGV/HFG
        JGE .+3;FCLA;FSTA WC;FSTA GMI
        JA G3
GUM2.   /DAMP UMAETTET
        BCAL:HG-HWK*WK!X1:HGS-HG*WE-X1!X1
        BCAL:PP*VG*F01+X1-GGV/VG/RG!HGP
G3.     STARTD
        FLDA INX1+2
        JEQ FM1
        STARTF
MID.    FLDA FMI;JNE MID1
        BCAL:HFP*DT+HF!HF
        FSUB HFS;JLT DHG
MID1    BCAL:HFS!HF!FMI
DHG.    FLDA GMI;JNE MID2
```

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```
        @CAL HGP*DT+HG'HG
        FSUB HGS,JGT DPDV
MID2    @CAL:HGS!HG'GMI
DPDV.   /UDREGN DELTA P OG VF
        @CAL PP*DT@P
        @CAL VFP*DT@VF
        @CAL:V-VF'VG
        @CAL TVP*DT@DTV
REG.    /BEREGN REGULERINGS INPUT VARIABLE
        @CAL.PB-P-QD
        JGT  +3;FCLA
        @CAL:+QK+Q0'Q
        FSUB QM,JLE .+4.FLDA' QM;FSTA' Q
        @CAL.P-PB-WKD
        JGT .+3;FCLA
        @CAL:+WKK+WK0!WK
        FSUB WKM;JLE .+4;FLDA' WKM;FSTA' WK
        @CAL:P-PB-WRD
        JGE .+5;FCLA;JA .+3;FLDA' WRM;FSTA WR
        FLDA WIST;JEQ WIRA
        FLDA TT;JLE FLUD
        FSUB DT;FSTA TT;JGT FLUD
        FLDA WI0;FSTA WI
WIRA.   FLDA TT:JGT WIRA1
        FLDA WIRP;JNE FLUD
        FLDA DOWI;FNEG;FSTA DOWI
        FLDA DWIT;FSTA TT
        FLDA F1;FSTA WIRP'
        FLDA TT
WIRA1.  FSUB DT;FSTA TT
        FLDA DOWI;FADDM WI
FLUD.   JSA UDL
        STARTD
        FLDAA D1
        FNEG
        FADDMA INDX1+2
        JA FOP
        /
        /UDLAES VARIABLE
UDL.    JA 0
        @FIX:0.P.PG.SP.OVA0
        @FIX:1.VF.VFG.SVF.OVA1
        @FIX:2.WE..SWE.OVA2
        @FIX:3.WC..SWC.OVA3
        @FIX:4.WK..SWK.OVA4
        @FIX:5.WR..SWR.OVA5
        @FIX:6.Q..SQ.OVA6
        @FIX:7.PP..SPP.OVA7
        /
        SETX INDX1
        FLDA FWI          /INDX1(0)=1 FOR VAND MAETNING
        JEQ .+5
        FLDA' F1
        JA .+3
        FCLA
        STX 0
        FLDA GMI          /INDX1(1)=1 FOR DAMP MAETNING
        JEQ .+5
        FLDA' F1
        JA .+3
        FCLA
        STX 1
        JA UDL
/
        INDEX 0

OVA2,   TRAP6 2
OVA3,   TRAP6 3
OVA4,   TRAP6 4
OVA5,   TRAP6 5
OVA6,   TRAP6 6
OVA7,   TRAP6 7
```


APPENDIX J

Program listing for the detailed steam generator model, a set of IC-values and an input-output example.

```
C       FILE  P3.FT
C       DAMPGENERATORMODEL SEP 74
C
        DIMENSION TP(40),TR1(40),TR2(40),TS(20),ALF(20),TD(21)
        DIMENSION DTR1(40)
        REAL LC,LR,LF,LAR
C
        DATA AS,AP,AR,AF,AD/5.16,1.835,4.63,9.77,.687/
        DATA LC,LR,LF,DZ/10.11,2.725,2.725,.5055/
        DATA OS,OP,OR/237.,210.,223./
        DATA VR,VE,VFL,VFH,VDO,VPI/12.6,75.,10.8,7.8,6.94,4.57/
        DATA DEP,DES,DED,DR/.0197,.0436,.136,.00127/
        DATA BH,CRN,LAR,CPR/4.96,.49,.014E-3,.94/
        DATA S,PC,DT/1.5,0.,.05/
        DATA HP,CL,TPI,TFI/0.,0.,0.,0./
C       MEAN VALUE OF ALFA IN RISER,USED FOR MINOR IMPORTANT TERMS
        DATA ALFRM/.5/
C
        COR=LAR*OR/DR
        COP=.023E-3*OP/(DEP**.2*AP**.8)
        COS1=.023E-3*OS/(DES**.2*AS**.8)
        COS2=1.972E-3*OS
        DSAR=AD/AS
        LCD=LC*AD/AS
        LFD=LF*AD/AF
        LRD=LR*AD/AR
        VER=ALFRM*VR+VE
        SVF=VFL+VFH+VDO+(1-ALFRM)*VR
        VRORS=VR/AS
        FK1=.092*DZ*.0425/(DES**1.2)
        FK2=.092*2*LC*.0425/(DED**1.2)
C
C       READ IC VALUES
100     READ (5,101)TP,TR1,TR2,TS,TD,ALF,P,PP,WS,XB,ALFR,VD,TP1,TPU,
     *  WP,CL,TPI,TFI
101     FORMAT (E13.6)
C
C       READ MAIN INPUT VARIABELS
110     WRITE (4,115)
115     FORMAT (1H0,"WP,CL,TPI,TFI:")
120     READ (4,125)WPN,CLN,TPIN,TFIN
C       READ STEPINDIKATOR (0) OR RAMPINTERVAL (NUMBER OF DT)
        WRITE (4,126)
        READ (4,145)NT
        NT=NT+1
        DWP=(WPN-WP)/NT
        DCL=(CLN-CL)/NT
        DTPI=(TPIN-TPI)/NT
        DTFI=(TFIN-TFI)/NT
        T=0
        PPO=0
125     FORMAT (4F10.4)
126     FORMAT (1H0,"NT:(XXX)")
C
C       READ COMPUTING AND OUTPUT INTERVALS (NUMBER OF OUTPUTS
C       AND OF DT PER OUTPUT)
130     WRITE (4,135)
135     FORMAT (1H0,"M,N:(XXX)")
140     READ (4,145)M,N
145     FORMAT (2I3)
C
200     DO 330 K=1,M
205     DO 299 L=1,N
        IF (NT)210,210,206
206     WP=WP+DWP
        TPI=TPI+DTPI
        TFI=TFI+DTFI
        NT=NT-1
C
C       CALCULATE WATER-STEAM PARAMETERS
210     TSA=(((-.25717E-5*P+.72476E-3)*P-.079614)*P+5.0121)*P+137.88
        IF ((P-PC)*(P-PC)-.01)220
215     PC=P
        HFG=(-.017199*TSA+3.2023)*TSA+1991.2
        RFS=(-.41304E-2*TSA+.54104)*TSA+922.02
        RGS=((.141687E-4*TSA-.76823E-2)*TSA+1.53481)*TSA-104.953
        DRFS=((.10129E-5*TSA-.93665E-3)*TSA+.29584)*TSA-33.314
        DRGS=(.14787E-4*TSA-.59017E-2)*TSA+1.0922
        DHFS=((-.64176E-5*TSA+.56767E-2)*TSA-1.7121)*TSA+180.65
        DHGS=((-.23142E-5*TSA+.20824E-2)*TSA-.63723)*TSA+64.714
        CP=((.57419E-9*TSA-.31531E-6)*TSA+.61417E-4)*TSA+.22556E-3
        C1=AS*RFS/DT
        C2=HFG*RGS/1000
        C3=(RGS*DHGS+HFG*DRGS)/1000
        C4=RFS*DHFS/1000
        C6=DRGS/RFS
        C7=DRFS/RFS
        C8=RGS/RFS
        RC1=RFS*DHFS/HFG
        RC2=VER*(-100+RGS*DHGS)/HFG
        HS2=COS2*EXP(P/43.4)
C
C       CALCULATE INLET TEMP. TO CORE
220     TAUP=VPI*RFS/WP
        TP1=(DT*TPI+TAUP*TP1)/(DT+TAUP)
C
C       CALCULATE CHANGES IN TR1 PROFILE
        HP=COP*WP**.8
        TB=TP1
        ASSIGN 225 TO R
        DO 229 J=1,40
        TA=(TB+TP(J))/2
        T1=TR1(J)
        T2=TR2(J)
        GO TO 600
225     DTR1(J)=.5*DTR
229     CONTINUE
C
C       CALCULATE CHANGES IN TR2 PROFILE
230     HS1=COS1*WS**.8*(.875+.0012*(TSA-250))
        TB=TD(21)
        Z=-1
        ASSIGN 235 TO R
        DO 239 J=1,20
        TA=(TB+TS(J))/2
        T1=TR1(J)
        T1O=TR1(41-J)
        T2=TR2(J)
        T2O=TR2(41-J)
        GO TO 610
235     TR2(J)=TR2(J)+.5*DTR
        TR2(41-J)=TR2(41-J)+.5*DTRO
239     CONTINUE
C
C       CALCULATE NEW TP AND TR1 PROFILE
240     TB=TP1
        ASSIGN 245 TO R
        DO 249 J=1,40
        TA=(TB+TP(J))/2
        T1=TR1(J)+DTR1(J)
        T2=TR2(J)
```



```
        GO TO 600
245     TP(J)=TB
        DTR=DTR1(J)+.5*DTR
        TR1(J)=TR1(J)+DTR
        [illegible]1(J)=.5*DTR
249     CONTINUE
C
C       [illegible]CULATE NEW TS,TR2 AND ALFA PROFILE
250     [illegible](21)
        [illegible]
        [illegible] 255 TO R
        [illegible] J=1,20
        [illegible]TS(J))/2
        [illegible](J)-DTR1(J)
        [illegible](41-J)-DTR1(41-J)
        [illegible](J)
        [illegible](41-J)
        [illegible]ALF(J))/2
        [illegible] 610
        [illegible]R2(J)+.5*DTR
        [illegible]TR2(41-J)+.5*DTRO
        [illegible]*(AA*C3+(1-AA)*C4-.1))/C2
        [illegible]+(1-AA)*C7)
        [illegible]*(C8-C8*C8)+(1-ALF(J)*(S-1))/DT)
        [illegible]ALF(J)/DT))
        [illegible]).5)/(2*A)
        [illegible]
C       [illegible] VELOCITY
        [illegible]
C       [illegible] LEVEL AND TEMP. IN RETURNLOOP
        [illegible]
        X=DT/(RFS*VFL)
        TD(1)=(TD(1)+X*(WB*TS(20)+CPR*WI*TFI))/(1+X*(WB+CPR*WI))
        X=WS*DT/(RFS*AD*DZ)
        DO 265 J=2,21
265     TD(J)=(X*TD(J-1)+TD(J))/(X+1)
C
C       CALCULATE OUTLET TEMP.
        TPU=(DT*TP(40)+TAUP*TPU)/(DT+TAUP)
C
299     CONTINUE
```

IC-values according to statement 100

```
C
C      OUTPUT TO TIME N*DT
       T=T+N*DT
300    WRITE (7,310)TP1,TR1(1),TR2(1),TD(21),T,TPU,TR1(40),
     * TR2(40),TS(20),P,XB,WL,WS,WG,WF,ALF(20)
310    FORMAT (/,4F8.1,16X,"T=",F6.1,/,4F8.1,/,2F8.2,4F8.1,F8.4)
320    CONTINUE
C
C      FINISHED TO TIME M=N*DT
400    WRITE (4,410)
       READ (4,420)I
       GO TO (430,110,130,500,550),I
410    FORMAT (///1X,"STOP/START/CONT./IC DATA/PROFILE 1/2/3/4/5.")
420    FORMAT (I1)
430    STOP
C
C      IC DATA OUTPUT
500    WRITE (6,101)TP,TR1,TR2,TS,TD,ALF,P,PP,WS,XB,ALFR,VD,TP1,TPU,
     * WP,CL,TPI,TFI
       GO TO 400
C
C      PROFILE OUTPUT
550    WRITE (7,560)TPI,TD(21),TP1,TPU
       DO 555 J=1,20
       WRITE (7,565)ALF(J),TS(J),TP(J),TR1(J),TR2(J),
     * TR2(41-J),TR1(41-J),TP(41-J)
555    CONTINUE
560    FORMAT (////,16X,F8.1,/,8X,2F8.1,32X,F8.1)
565    FORMAT (F8.4,7F8.1)
       GO TO 400
C
C      COMMON ROUTINES
600    RF=((-.54202E-4*TA+.036496)*TA-9.454)*TA+1740.9
       CPP=((((.26327E-13*TA-.87750E-11)*TA-.28309E-8)*TA
     * +.77403E-6)*TA+.20448E-3)*TA-.42044E-1
       V=AP*RF/DT
       QP=WP*((.15503E-4*TA-.77280E-2)*TA+1.0257)*(TA-T1)
       QR=CQR*(T1-T2)
       TB=(TB*WP/DZ-QP/CPP+V*TP(J))/(WP/DZ+V)
       DTR=DT/CRW*(QP-QR)
       GO TO R
C
610    QR=CQR*(T1-T2)
       QRO=CQR*(T1O-T2O)
       QS1=WS1*(T2-TA)
       QS2=WS2*(T2-TSA)*(T2-TSA)
       IF (QS2-QS1)611
       QS1=QS2
611    QSO1=WS1*(T2O-TA)
       QSO2=WS2*(T2O-TSA)*(T2O-TSA)
       IF (QSO2-QSO1)612
       QSO1=QSO2
612    DTR=DT/CRW*(QR-QS1)
       DTRO=DT/CRW*(QRO-QSO1)
       QS=QS1+QSO1
       IF (-Z)613
       V=TB
       TB=(TB*WS/DZ+QS/CP+C1*TS(J))/(WS/DZ+C1)
       IF (TB-TSA)613,613
       Z=(TB-TSA)/(TB-V)
       TB=TSA
613    GO TO R
       END
```

0.317438E+03
0.315909E+03
0.314413E+03
0.312952E+03
0.311527E+03
0.310130E+03
0.308787E+03
0.307472E+03
0.306195E+03
0.304955E+03
0.303753E+03
0.302587E+03
0.301457E+03
0.300363E+03
0.299304E+03
0.298279E+03
0.297288E+03
0.296330E+03
0.295404E+03
0.294510E+03
0.293645E+03
0.292811E+03
0.292005E+03
0.291227E+03
0.290476E+03 T_p
0.289751E+03
0.289051E+03
0.288376E+03
0.287724E+03
0.287095E+03
0.286489E+03
0.285903E+03
0.285339E+03
0.284794E+03
0.284268E+03
0.283761E+03
0.283272E+03
0.282800E+03
0.282344E+03
0.281904E+03
0.307913E+03
0.306604E+03
0.305483E+03
0.304310E+03
0.303167E+03
0.302054E+03
0.300972E+03
0.299920E+03
0.298898E+03
0.297907E+03
0.296946E+03
0.296014E+03
0.295112E+03
0.294239E+03 T_{r1}
0.293394E+03
0.292577E+03
0.291787E+03
0.291023E+03
0.290285E+03
0.289572E+03
0.288883E+03
0.288218E+03
0.287576E+03
0.286956E+03
0.286358E+03

0.285788E+03
[illegible]

0.268392E+03
0.268392E+03
0.268392E+03
0.268392E+03
0.268392E+03
0.268392E+03
0.268392E+03
0.268392E+03
0.268392E+03
0.263982E+03
0.263982E+03
0.263982E+03
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0.263982E+03
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0.263982E+03
0.263982E+03
0.263982E+03
0.263982E+03 T_d
0.263982E+03
0.263982E+03
0.263982E+03
0.263982E+03
0.263982E+03
0.263982E+03
0.263982E+03
0.263982E+03
0.263982E+03
0.000000E+00
0.491039E-03
0.115489E+00
0.206254E+00
0.279001E+00
0.340623E+00
0.391792E+00
0.435470E+00
0.473214E+00
0.506192E+00 α
0.535271E+00
0.561141E+00
0.584326E+00
0.605240E+00
0.624246E+00
0.641500E+00
0.657512E+00
0.672196E+00
0.685803E+00
0.698462E+00
0.537857E+02 p
-0.133330E-03 $\dot{p}$
0.431996E+04 W_s
-0.660146E-02 X_0
0.698463E+00 α_f
0.816953E+01 v_d
0.319000E+03 T_{p1}
0.281905E+03 T_{pu}
0.423000E+04 W_p
0.883000E+01 c_l
0.319000E+03 T_{pi}
0.226000E+03 T_{fi}
0

Input-output example.

Underlined text : operators input

```
.R FRTS
•P3
•P3100 IC/S
•P3 IC</6
•/7=4/C
•1

WP.CL.TP1.TF1
4230 .8 03.319 .226

NT (XXX)
0

M.N (XXX)
2.50

   319.0   307.9   275.4   264.0                        T=   2.5
   281.9   279.5   271.8   268.4
   53.79   -0.01   474.9  4319.9   474.9  3844.9  0.6985

   319.0   307.9   275.4   264.0                        T=   5.0
   281.9   279.5   271.8   260.4
   53.79   -0.01   474.9  4319.9   474.9  3844.9  0.6985

STOP/START/CONT./IC DATA/PROFILE:1/2/3/4/5:

2

WP.CL.TP1.TF1:
4230..8 03.329..226.

NT:(XXX)
0

M.N:(XXX)
10.40

   320.0   315.0   276.3   264.0                        T=   2.0
   281.9   279.6   272.0   260.6
   53.99    0.02   476.7  4312.2   494.1  4069.9  0.6943

   320.9   316.0   277.1   264.2                        T=   4.0
   282.5   280.0   272.9   269.4
   54.73    0.09   483.3  4351.8   517.3  3815.4  0.7140

   329.0   316.3   277.9   264.5                        T=   6.0
   284.7   282.0   274.0   270.4
   55.61    0.05   491.8  4345.1   523.0  3481.0  0.7307

   329.0   316.5   278.6   264.0                        T=   8.0
   286.1   283.7   274.8   271.3
   56.30   -0.02   497.8  4259.0   516.4  3622.4  0.7170

   329.0   316.6   279.1   265.3                        T=  10.0
   286.0   284.3   275.4   271.8
   56.80   -0.04   503.2  4207.1   515.7  3729.0  0.7084

   329.0   316.7   279.5   265.9                        T=  12.0
   287.3   284.7   275.0   272.2
   57.28   -0.03   505.5  4199.1   517.7  3692.2  0.7095

   329.0   316.8   279.8   266.3                        T=  14.0
   287.6   285.8   276.1   272.6
   57.57   -0.03   508.3  4190.0   518.6  3672.1  0.7096

   329.0   316.8   280.0   266.7                        T=  16.0
   287.9   285.3   276.4   272.9
   57.84   -0.03   510.7  4193.8   519.2  3671.8  0.7085

   329.0   316.9   280.2   267.0                        T=  18.0
   288.2   285.5   276.6   273.1
   58.06   -0.03   512.6  4190.8   519.6  3671.1  0.7078

   329.0   316.9   280.4   267.3                        T=  20.0
   288.3   285.7   276.8   273.3
   58.24   -0.03   514.3  4189.7   519.9  3673.5  0.7073

STOP/START/CONT./IC DATA/PROFILE:1/2/3/4/5:

3

M.N:(XXX)
6.100

   329.0   317.0   280.7   267.8                        T=  25.0
   288.7   286.0   277.2   273.7
   58.50   -0.03   517.2  4186.2   520.9  3665.6  0.7065

   329.0   317.0   280.9   268.1                        T=  30.0
   288.9   286.2   277.4   273.9
   58.79   -0.03   519.1  4184.9   521.5  3664.2  0.7059

   329.0   317.1   281.1   268.3                        T=  35.0
   289.0   286.4   277.5   274.1
   58.93   -0.02   520.4  4184.4   521.0  3665.1  0.7055

   329.0   317.1   281.1   268.4                        T=  40.0
   289.1   286.4   277.6   274.2
   59.02   -0.02   521.2  4183.7   522.1  3663.9  0.7053

   329.0   317.1   281.2   268.5                        T=  45.0
   289.2   286.5   277.7   274.2
   59.08   -0.02   521.7  4182.9   522.3  3660.2  0.7051

   329.0   317.1   281.2   268.5                        T=  50.0
   289.2   286.5   277.7   274.3
   59.12   -0.02   522.0  4183.3   522.4  3661.9  0.7051

STOP/START/CONT./IC DATA/PROFILE:1/2/3/4/5:

3

M.N:(XXX)
5.200
```



```
   329.0   317.1   281.3   268.6                        T=  60.0
   289.3   286.6   277.8   274.3
   59.16   -0.02   522.4  4182.1   522.6  3658.7  0.7049

   329.0   317.1   281.3   268.6                        T=  70.0
   289.3   286.6   277.8   274.3
   59.18   -0.02   522.6  4182.1   522.6  3659.6  0.7049

   329.0   317.1   281.3   268.6                        T=  80.0
   289.3   286.6   277.8   274.3
   59.18   -0.02   522.6  4182.3   522.7  3659.7  0.7049

   329.0   317.1   281.3   268.6                        T=  90.0
   289.3   286.6   277.8   274.3
   59.19   -0.02   522.6  4182.4   522.7  3659.0  0.7049

   329.0   317.1   281.3   268.6                        T= 100.9
   289.1   286.6   277.8   274.4
   59.19   -0.02   522.7  4182.4   522.7  3659.0  0.7049

STOP/START/CONT./IC DATA/PROFILE:1/2/3/4/5:

3

                  329.0
           [illegible]  329.0                                          289.3
 [illegible]  [illegible]  [illegible]  317.1  281.3  277.8  286.6  289.3
 [illegible]  [illegible]  [illegible]  315.9  281.2  277.9  287.0  289.8
 [illegible]  [illegible]  [illegible]  314.7  281.1  277.9  287.4  290.3
 [illegible]  [illegible]  [illegible]  313.5  281.0  278.0  287.8  290.8
 [illegible]  [illegible]  [illegible]  312.3  280.9  278.1  288.3  291.4
 [illegible]  [illegible]  [illegible]  311.2  280.8  278.1  288.7  292.0
 [illegible]  [illegible]  [illegible]  310.1  280.6  278.2  289.2  292.6
 [illegible]  [illegible]  [illegible]  309.0  280.5  278.3  289.7  293.2
 [illegible]  [illegible]  [illegible]  307.9  280.4  278.3  290.2  293.8
 [illegible]  [illegible]  [illegible]  306.8  280.3  278.4  290.7  294.5
 [illegible]  [illegible]  [illegible]  305.8  280.2  278.5  291.3  295.1
 [illegible]  [illegible]  [illegible]  304.8  280.1  278.6  291.8  295.8
 [illegible]  [illegible]  [illegible]  303.8  280.0  278.7  292.4  296.6
 [illegible]  [illegible]  [illegible]  302.9  279.9  278.7  293.0  297.3
 [illegible]  [illegible]  [illegible]  302.0  279.8  278.8  293.6  298.1
 [illegible]  [illegible]  [illegible]  301.1  279.7  278.9  294.3  298.9
 [illegible]  [illegible]  [illegible]  300.2  279.6  279.0  294.9  299.7
 [illegible]  [illegible]  [illegible]  299.4  279.5  279.1  295.6  300.6
 [illegible]  [illegible]  [illegible]  298.6  279.4  279.2  296.3  301.5
 [illegible]  [illegible]  [illegible]  297.8  279.3  279.2  297.1  302.4

[illegible]/PROFILE:1/2/3/4/5:

[illegible]/PROFILE:1/2/3/4/5:
```

APPENDIX K

List of files on DEC-tape "PNR DEC.74"

```
TAPE: PWR DEC. 1974
/
FPL.FP: FLAP LIBRARY FILE, DEC'S SYSTEM
SL.FP:  FLAP LIBRARY FILE, HYBAL SYSTEM
HSL.FP: FLAP SYMBOL TABLE EXTENSION
ML.ML:  8BAL LIBRARY FILE, HYBAL SYSTEM
/
P1.FT: TEN-SHELL SEXTION FUEL MODEL
P1.LD: DO IN LOAD FORMAT
P3.FT: STEAM GENERATOR MODEL
P3.LD: DO IN LOAD FORMAT
P3100.IC: IC-FILE FOR DO, 100% LOAD
/
P2.8B: PRESSURISER MODEL
P2.SV: DO IN SAVE FORMAT
/
PWR.8B: PWR PLANT MODEL, PDP8 CODE SECTION
PWR1.8B:       DO      , FPP CODE SECTION 1
PWR2.8B:       DO      ,   DO        DO   2
PWR3.8B:       DO      ,   DO        DO   3
PWR.SV:        DO       IN SAVE  FORMAT
PWR.IC: IC-FILE FOR DO
PWR.ST: STATIK DATA FOR DO
PWR.SP: POTENTIOMETER FILE FOR DO
```

```
 12/16/74
LABEL        2 12/16/74
FPL   .FP   58 6/14/73
SL    .FP   26 10/29/74
HSL   .FP    2 2/12/74
ML    .ML   31 11/15/74
P1    .FT    7 12/10/74
P1    .LD   15 12/10/74
P3    .FT   17 12/10/74
P3    .LD   19 12/10/74
P3100 .IC    8 12/10/74
P2    .8B   18 12/4/74
P2    .SV   14 12/4/74
PWR   .8B   33 12/16/74
PWR1  .8B   16 12/6/74
PWR2  .8B   26 12/11/74
PWR3  .8B   20 11/25/74
PWR   .SV   37 12/11/74
PWR   .IC    3 12/16/74
PWR   .ST   30 12/16/74
PWR   .SP    5 12/11/74
<EMPTY>    343
 343 FREE BLOCKS

*
```


APPENDIX L

Example of logging of main variables for the power plant model.

```
FLUX:
   1.507 E+013
   2.062 E+014   3.313 E+014   3.881 E+014   3.970 E+014   3.888 E+014
   3.592 E+014   3.491 E+014   3.397 E+014   3.506 E+014   3.609 E+014
   3.487 E+014   3.150 E+014   2.595 E+014   1.815 E+014
   1.416 E+013

NUKLEAR EFFEKT I MW:
   120.3   192.7   224.0   228.0   218.4   204.9   198.0
   192.2   198.2   203.9   195.9   175.9   144.1   100.3

URAN TEMP.:
   474.5   611.0   679.3   692.3   675.2   651.3   642.5
   632.5   648.6   663.5   650.5   614.2   556.3   479.4

KAPSEL TEMP.:
   295.9   306.4   313.1   317.0   319.1   320.0   323.0
   325.1   328.5   331.9   333.7   334.0   332.5   329.2

VAND TEMP.:
   281.7
   283.5   286.5   289.9   293.3   296.6   299.5   302.4
   305.2   307.9   310.7   313.3   315.6   317.5   318.8
   318.9

VAND TAETHED:
   .7602
   .7604   .7550   .7492   .7424   .7358   .7294   .7236
   .7175   .7114   .7053   .6987   .6921   .6865   .6823
   .6838

VOID I %:
     .00     .01     .02     .03     .05     .06     .00
     .11     .15     .20     .27     .36     .44     .52

FASTE KONTROLSTAENGER:
    .000
    .000    .100    .200    .300    .400    .500    .400
    .300    .150    .000    .000    .000    .500    .000
    .000

REAKTOR EFFEKT :  2597.6
REG.STANG POS.  :   .5112
REG.STANG VAEGT:   .2500
BOR KONCENTRATION I PPM:  1440.7
PRIMAER TRYK:  140.64
PRIMAER MAETNINGSTEMP. : [illegible]
DAMPTRYK : [illegible]
DAMPTEMP. : [illegible]
DAMP [illegible]
HP [illegible]
LP [illegible]
EL [illegible]
```